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Influence of UV Exposure on Properties of Wool Fiber Pretreated with Surfactants Solutions

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The influence of wool fiber pretreatment with aqueous solutions of sodium laurylsulphonate, alkylphenolethoxylate or benzyl alcohol on mechanical properties and colour changes of wool fiber occurring during UV irradiation were examined. The changes of wool fiber properties were estimated using measurements of tensile strength, elongation at breake, yellowness index and lightness. The data have shown a higher relative tensile strength of pretreated with nonionic surfactant and irradiated wool fiber sample comparing to ones pretreated with anionic surfactant. Abrasion testing results have shown that the resistance of irradiated wool fabric to abrasion were related with yellowness index values.

Keywords: wool fiber, surfactant, nonionic, anionic, benzyl alcohol.

INTRODUCTION

The way that light affects hair is still not completely understood, but there are papers announcing that the exposure of hair to light causes chemical and physical degradation of the fiber [1]. The deleterious effects of solar irradiation are perceived as changes in texture and color, dryness, etc., and can be evaluated in terms of reduced elasticity, increased porosity or swelling properties, altered dye sorption characteristics, and photofading of natural or artificial hair color.

Reutsch *et al* announced radiation-induced changes in the physical and in chemical nature of the hair fiber [2]. They have shown that high levels of photodegradation products are formed throughout the hair fiber cross section during long-term expose in the 290 nm – 400 nm range.

Using scanning electron microscope Zimmermann and Hocker established that fibers were stable during 12 hours of UV irradiation [3]. Beyond that time and up to approximately 48 hours the strength decreased at a faster rate: on further irradiation, the decrease reduced and was linear with irradiation time.

Auxiliaries or surfactants in scouring solutions are used to eliminate contaminants from wool fiber. Non-eliminated contaminants may be a reason of wool fiber damage during subsequent operations [4, 5].

O. Kyunwha's *et al* [6] have postulated that molecules of anionic sodium n-alkylsulphates adsorbed on wool fibers increase the negative charge on the fiber surface and tend to repel perhydroxy anions from hydrogen peroxide as well as alkali hydroxyl anions, resulting in a reduction of fiber damage, while with cationic dodecyltrimethylammonium bromide the results were opposite.

The bibliographic data indicate, that when dyed wool fabrics were pretreated with solutions of nonionic surfactant, it was observed the increase in abrasion resistance [7].

Moreover a series of publications is devoted to show that the pretreatment of wool fiber with nonionic surfactant enhance the dye exhaustion and the leveling of dyeing [8 – 11].

Based on the results of our previous work, we hypothesized that the damage of wool fiber caused by UV irradiation should be lower rather after pretreatment with an aqueous solution of nonionic alkylphenol ethoxylate than with anionic sodium laurylsulphonate.

The objective of this study was to carry out tensile testing of wool fibers after UV irradiation of pretreated with aqueous solution wool fabric and to compare the results with abrasion resistance and yellowness index as well as lightness, the characteristics being as indicators of the level of degradation of wool fiber.

In the previuos article we have reported that the decrease of tensile strength for wool fibers of loomstate fabrics after UV irradiation 40 – 120 hours was in the range of 8 % – 20 % [12]. In the present investigation we applied the "Xenotest" UV irradiation during 20, 50 and 80 hours.

EXPERIMENTAL

Materials. An all-wool fabric which corresponds to ISO 105/F-1985 (E) standard conditions was used in all experiments. In this work the samples of mentioned fabric are denominated as untreated samples.

Nonionic alkylphenolethoxylate (NPE) – "Lanasan LT" produced by "Clariant" and anionic sodium laurylsulphonate (SLS) – "Polystep B3" produced by "Stepan" as well as benzyl alcohol (BA) were used as auxiliaries for pretreatment of wool fabric. The benzyl alcohol was of reagent purity.

Fabric pretreatments. Samples of untreated wool fabric in the state such as received were scoured with aqueous solutions of nonionic, anionic surfactants or benzyl alcohol. The pretreatments were carried out for 45 min at 30 °C, using 5 % w/w solution of appropriate surfactant or 3 % of v/v, liquor ratio was 1 : 30. After pretreatment the

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samples of fabric were rinsed with distilled water until pH of solution became neutral.

UV exposures of wool samples. Samples of wool fabric were exposed to UV irradiation in a "Xenotest 150S" apparatus housing a xenon arc lamp 1.1 kW – 1.5 kW. The relative humidity was controlled to 60 % ±2 % and the temperature to 20 °C ±2 °C. Irradiation time was 20, 50, 80 hours.

Instrumentation. Tensile strength and elongation at break of wet elementary wool fibers were measured. Elementary wool fibers were carefully released untwisting them from warps.

Tensile testing was performed using a "Digital Electronic Fiber Tester FM-27". Testing conditions: initial distance between clamps was 1 cm, stretching speed 10 mm/min. The average values of tensile test were calculated from 100 measurements.

Elongation at break *El* (%) is calculated using the following equation:

$$El = 100\ \Delta l / l_0, \quad (1)$$

where Δl is the extention of elementary wool fiber at break, mm; l_0 is the initial length of fiber, mm. Relative elongation at break E_R (%) was calculated respectively to F_R.

The relative tensile strength F_R (%) was calculated using formula:

$$F_R = 100\ (F_1 - F_2) / F_1, \quad (2)$$

where F_R is the relative tensile strength, dN; F_2 is the tensile strength after exposure, dN; F_1 is the tensile strength before exposure, dN.

Abrasion tests. Abrasion tests were performed using a "FF-21" device (Hungary). Abrasion conditions: samples of the fabric were of particular initial mass, quantity of abrasion cycles was 400, load was 50 g/cm^2, flip-side of sandpaper as abrasive was used. All samples before and after the abrasion tests were retained in standard climatic conditions for 24 h. Three abrasion tests were proceeded for every sample.

Relative resistance to abrasion ΔM (%; "Delta M" in the Fig. 1) was calculated using equation:

$$\Delta M = 100\ (M_1 - M_2) / M_1, \quad (3)$$

where M_1 is the mass of the sample before abrasion, g; M_2 is the mass of the sample after abrasion, g.

Color test. "Spectraflash SF 600PLUS CT" (Datacolor International spectrophotometric system) device was used for estimation of digital parameters of wool fabric color. Selected parameters of "CIELAB" color space were: difference of lightness ΔL and lightness L and total color difference ΔE. Parameters L^*, ΔL^*, ΔE are given in NBS units.

Yellowness index *YI* (%) was calculated according to the following equation:

$$YI = 100\ (1.28X - 1.06Z) / Y, \quad (4)$$

where X, Y, Z are the color coordinates of the sample.

Difference of the yellowness index ΔYI was calculated according the equation:

$$\Delta YI = 100\ (YI_1 - YI_2) / YI_1, \quad (5)$$

where YI_1 is the yellowness of initial sample; YI_2 is the yellowness of irradiated sample.

RESULTS AND DISCUSSIONS

The data presented in Table 1 show a higher loss of tensile strength when to UV irradiation were exposed wool pretreated with *SLS* comparing with that of untreated. However, the losses of strength for the wool fiber pretreated with *NPE* or *BA* were significantly lower. The results obtained allow to assume that the wool fiber pretreated with *NPE* or *BA* was more stable to UV irradiation comparing with untreated and significantly more stable compared with that for pretreated with *SLS*.

Table 1. Effects of UV irradiation* on properties of wool fibers pretreated with different auxiliaries

Samples	F_R, %	E_R, %
Untreated	71.0	45.7
Pretreated with:		
NPE	74.4	59.1
SLS	66.0	43.7
BA	81.5	66.6

*time of UV exposure 80 h.

The data presented in Figure 1 show that the losses of mass of wool fabric in the abrasion test of pretreated with *NPE* or *SLS* fabric samples were almost alike.

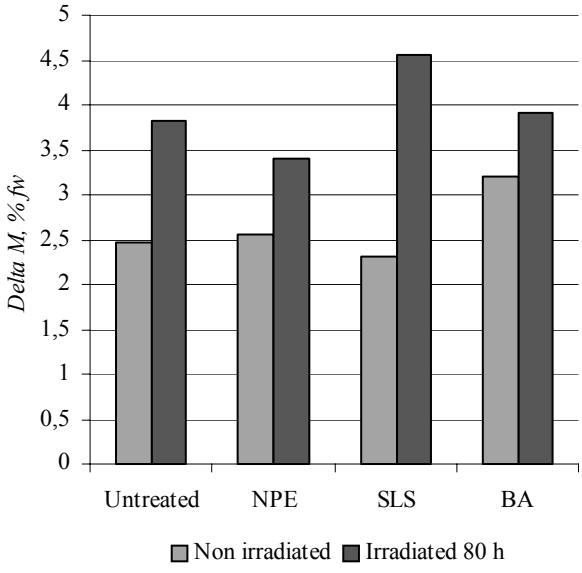

Fig. 1. Resistance to abrasion of differently pretreated wool fabrics

The most significant decrease of tensile strength as well as elongation at break of the fibers in the case of anionic surfactant could be explained by the tendency of sulphonate groups to interact with basic groups of wool fiber. Thus, the net of relatively strong ionic bonds could be weakened and the resistance of wool fiber external forces was weakened as well. The amount of anionic surfactant *SLS* at 30 °C absorbed by wool fiber at equilibrium, as it has been determined earlier, is *ca* 2.4 % f.w., while that for nonionic alkylphenolethoxylate *NPE* is 0.6 % [13].

UV irradiation for 80 h generally has lowered the resistance of wool fabric abrasion. However, the losses of mass for all examined samples were different. Samples

pretreated with *NPE* manifested the lowest increase in loss of mass of fabric in the test of abrasion. *SLS* in terms of abrasion reduced the resistance of wool fabric to photodegradation in term of abrasion more compared with that for *NPE*.

The measurement of yellowness index *YI* variation, which occurs due to the exposure of fabric to UV irradiation, can be useful in wool fiber damage identification. UV irradiation on wool fiber influences yellowing and is related to photodegradation of keratin fiber and with the losses of strength, elasticity and an increase in porosity and swelling of the fiber [14, 15].

The data presented in Figure 2 show a sharp increase in *YI* for all examined samples at the initial stage of UV irradiation. When the duration of exposure was increased from 20 h up to 50 hours for all pretreated samples *YI* changed almost insignificantly. The results allow to assume, that surfactants used in this study or *BA* could be considered as the agents of wool fiber photostabilisation.

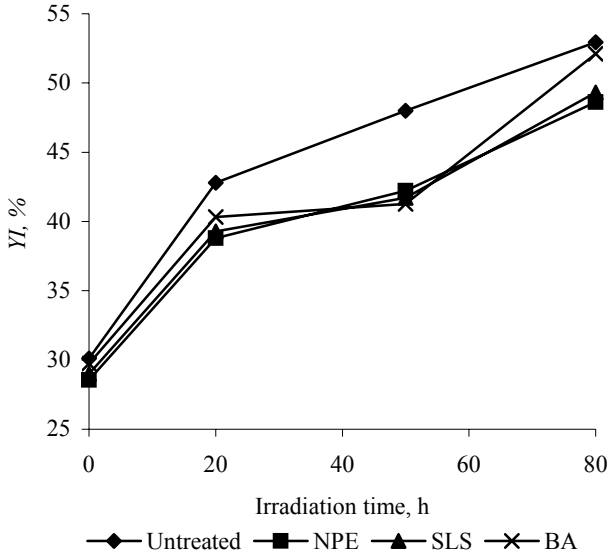

Fig. 2. Yellowness index *YI* of irradiated wool fiber samples

The data showing *YI* changes and the variation of abrasion test characteristic values occuring due to the exposure to UV irradiation of wool fabric are presented in Table 2. The results show a higher resistance of pretreated with *NPE* wool fabric alike the results of tensile testing (Table 1).

Table 2. Changes of *YI* and resistance to abrasion after UV exposure*

Samples	Δ*YI**, %	Δ*M*, %
Untreated	12.68	64.33
Pretreated with*:*		
NPE	10.23	72.38
SLS	10.29	54.03
BA	10.59	62.89

*20 h of irradiation.

As it is shown in Figure 3 for all wool samples in the range of UV irradiation the lightness *L* has decreased. This means that the samples examined became darker then initial ones. The effect of UV irradiation on darkening of wool fiber was particularly evident from the beginning of exposure. *YI* represent the total lightness, which was dependent on the absorbance of differently coloured melanines and products formed due to the degradation of various impurities of wool fiber [16]. The results of irradiation up to 80 h showed that for both with *SLS* or *NS* pretreated samples were slightly lighter as compared with untreated or pretreated with *BA*.

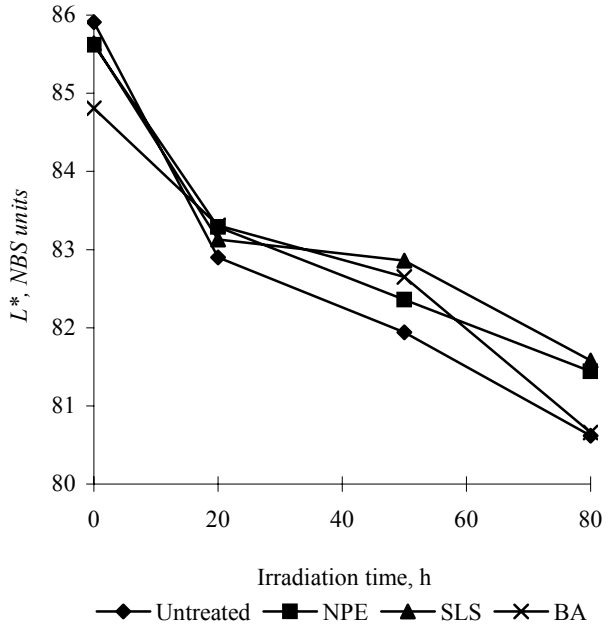

Fig. 3. Variation of lightness *L* of wool fabric during exposure to UV irradiation

Table 3. Changes of lightness (Δ*L**) and color difference (Δ*E)* of wool fabric

Samples	Δ*L**, NBS units	Δ*E***, NBS units
Untreated	-3.01	8.17
Pretreated with:		
NPE	-2.32	6.68
SLS	-2.51	6.65
BA	-1.49	7.01

**UV exposure 20 h.

The data presented in Table 3 show that the changes of lightness during UV irradiation were almost of the same level when the samples were pretreated with *NPE* or with *AS*. A lower lightness was observed for the samples, which were pretreated with *BA*. The total color difference for *NPE* and *SLS* pretreated samples were lower comparing with that for *BA* pretreated or untreated samples.

CONCLUSIONS

The study of UV irradiation influence on pretreated with nonionic or nonionic surfactant wool fabric degradation was done.

The results of investigation allowed to assume that a slower photodegradation of wool fiber occured when it was pretreated with nonionic surfactant as compared with that for pretreated with anionic surfactant.

A higher relative tensile strength of pretreated with nonionic surfactant and irradiated wool fiber sample comparing to pretreated with anionic surfactant was established. Abrasion testing results have shown that the resistance of irradiated wool fabric to abrasion were related with values of yellowness index.

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