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Effects of UV Absorbers on Cotton Fabrics

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ABSTRACT

Due to the ozone layer depletion, increased levels of UV rays start having wide ranging impacts on human health and welfare. Although the energy required to sustain life comes from the sun, acute or chronic overexposure to sunlight can lead to a variety of deleterious effects such as erythema (sunburn), photoaging, premalignant lesions and melanoma skin cancer. Clothing has the ability to protect the skin to an extent; but in many cases this protection may not be sufficient. The percentage of radiation transmitted by the fabric is a crucial factor that determines the level of protection. Fabrics that are treated with UV absorbers which have increased ability to attenuate light protect human skin from harms of solar radiation. UV absorbers can be incorporated into synthetic fibers in fiber spinning baths. They can also be applied as finishing agents. In this study, two types of 100% cotton fabrics have been used; twill 2/1 and rib 2/1. Following the application of preliminary processes, these fabric specimens were dyed with 0.1%Procion Brilliant Red HE-GXL (Dye-Star). UV absorbers were added before, during and after dyeing at the concentrations of 0 and 2 %. Transmittance values at 290-400 nm were measured. These values for undyed and dyed fabrics were used in the calculation of UPF and UV protection categories for each specimen were determined. Moreover, whiteness degrees of undyed specimens treated with UV absorbers were examined. The light fastness of dyed fabrics was also examined.

Key words: Cotton fabrics, light fastness, UV absorbers

Introduction

Nowadays, the depletion of the ozone layer has highlighted and ultraviolet radiation (UVR) reach the earth surface [1]. The experts agree that human exposure to UVR should be controlled by protecting the skin or limiting its exposure to UVR [2]. Therefore clothing is recommended by scientiests as one of the primary methods of protecting the skin [3]. To protect from over-exposure to UVR, it is recommended to avoid going out in the sun, to wear a sunscreen, or to cover up with clothing. The effectiveness of a sunscreen depends on the concentration of UV-absorbing agent in the sunscreen and the thickness of the film applied to the skin; if the sunscreen is applied sparingly, a higher concentration of UV absorbers is required to reduce the amount of radiation striking the skin [4].

UV absorbers are substances capable of selectively absorbing short wave solar radiation and of restoring the absorbed energy intact to the environment. They decrease the harmful effect of UV rays on human skin, as well as the textile material and dyes.

The need for and the effectiveness of protection of fibers against UV radiation depend on the type of fiber. Textile materials which have weak UV absorbing ability such as cotton may give relatively weak protection for human skin, although they are less at risk themselves. On the other hand, fabrics with strong UV absorption power containing intensely absorbing polymers or fibers containing delustrant pigments may have the risk of degradation.

The various components of a dyeing contribute in different ways to its absorption in the UV region. Where the photosensitivity of dyeings is concerned a distinction must be made between dye destruction induced by fiber degradation or other dyeing components, and the photosensitivity of the dye itself. Dye destruction induced by the UV absorption of other components can be largely influenced by UV absorbers.

The degree of protection of the skin against the action of solar radiation can be expressed as Sun

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Protection Factor (SPF) and Ultraviolet Protection Factor (UPF). Sun protection factor is the quantitative measure of an in vivo determination, and UPF is used to indicate the result obtained instrumentally.

The UV region constitutes roughly 7% of total solar emission reaching the earth. UVA rays (320-400nm) have much less effect on human skin compared to UVB rays (290-320 nm). UVC rays have shorter wavelengths (< 290 nm) and are absorbed by stratospheric ozone layer.

Measurement of UVR transmission and calculation of protection factors for fabric vary throughout the literature.

In Pailthorpe protection factors (SPF, UPF) were calculated from UV transmission data, solar irradiance data, and an erythenial-action spectrum. Other authors have used the terms relative protection factor (RPF), fabric protection factor (FPF), SPF and ultraviolet protection factor (UPF). ln addition, fabrics tested in previousstudies have not been adequately described, making it difficult to understand the influence of fabric parameters on UVR transmission [5-11].

The term 'UV absorbers' covers various organic and inorganic compounds having the common characteristic of marked absorption of UV radiation, virtually no absorption in the visible region and high light fastness. All organic compounds applied industrially in wet processes to textile fibers to date are derivatives of one of three different structures: o-hydroxybenzophenone; o-hydroxyphenylbenzotriazole; o-hydroxyphenyltriazine [12-17]. There are many reports about dyes, especially black and blue colors of production against UV radiation [18,19] and the effect of UV radiation production of the fabric structure [20,21].

2. Experimental:

2.1 Materials and apparatus:

Materials used:

Pretreated 100% cotton fabrics free from fluorescent brighteners were used.
Fabric construction:
Yarn counts: Warp: Ne 10/2 Weft: Ne 10/2
Fabric I: twill 2/1 weave;
Fabric II: rib 2/1 weave. Warp and weft density of all fabrics was 11 picks/cm.
Fabric densities: 272g/m² for fabric I and 269 g/m² for fabric II.

Auxiliary: Rayosan C-Clariant is a heterocyclic compound which forms a covalent bond with the cellulose macromolecule.

Apparatus:

UV visible spectrophotometer (Lambda 9 Perkin Elmer) was used for transmission measurements. Laboratory HT Dyeing Machine (Roaches Brand-MB) was employed for the applications of the UV absorbers and for the dyeing of the cotton fabric. Color measurements were performed on reflectance spectrophotometer (Datacolor International). Light Fastness Tester (James H. Heal) was used.

2.2 Method of application:

Application of the UV absorber (Rayosan C-Clariant) on white fabric

Rayosan C was applied to 5 g white fabric by the exhaustion process with the amount of 0% and 2% on weight of the material. 70 g/L Sodium sulphate and (2+ the amount of UV absorber) % Sodium carbonate were used. Liquor ratio was 10:1. Temperature-time diagram for the application of Rayosan C was shown in Figure 1.

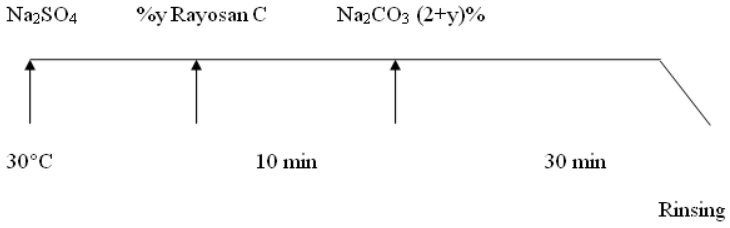


Fig. 1: Temperature-time diagram.

Dyeing process;

0.1% Procion Brillant Red HE-GXL (DyStar) reactive dye was used in the dyeings. 5 g samples were dyed by exhaustion and the liquor ratio was 10:1. At 60 ºC, the dyeing was carried out for 80 min. 180g/L NaCl and 20 g/L Na_2CO_3 were used in the dyeings. After dyeing, washing/rinsing stages were carried out shown in Table 1.

Table 1: Washing process

Process number	Post Processes	Conditions
1	Cold Washing	3 l /5g material
2	Neutralization with acetic acid	pH =7
3	Hot Rinsing	80 ºC – 2 min, 500 mL / 5 g material
4	Soaping at Boil	10min 400 ml/ 5g material
5	Cold Rinsing	1000 mL / 5 g material

UV absorbers were applied according to exhaust method. Each trial has been repeated three times. UV visible spectrophotometer was used for measuring the transmittance values according to AS/NZS 4399:1996 standard. The UV transmittance of each specimen has been measured at 5 nm intervals from 290nm to 400nm. UPF, UVA and UVB values have been calculated according to the equation 1 and 2 given in the above mentioned test standard.

$$UPF = \frac{E_{eff}}{E'} = \frac{\sum_{290}^{400} E_\lambda x S_\lambda x \Delta\lambda}{\sum_{290}^{400} E_\lambda x S_\lambda x T_\lambda x \Delta\lambda} \qquad \textit{[Equation 1]}$$

E_λ = Relative erythemal spectral effect
S_λ = Solar spectrum radiation (W.m $^{-2}$. nm^{-1})
T_λ = Spectral transmittance of the specimen
$\Delta\lambda$ = Wavelength intervals (nm)
λ = Wavelength , nm

$$UVA_{AV} = \frac{T_{315} + T_{320} + T_{325} + ... + T_{395} + T_{400}}{18} \qquad \textit{[Equation 2]}$$

$$UVB_{AV} = \frac{T_{290} + T_{295} + T_{300} + T_{305} + T_{310} + T_{315}}{6}$$

Table 2 shows the classification of sun protection effects of fabrics according to AS/NZS 4399:1996 Standard.

3. Results:

The % transmission values of untreated, bleached and UV absorbed fabrics are given Figure 2 and 3.

Table 2: UPF classification [5].

UPF range	UVR protection category	UVR transmittance (%)	UPF grading
15-24	Good protection	6.7-7.2	15, 20
25-39	Very good protection	4.1-2.6	25, 30, 35
40-50 , 50+	Excellent protection	≤2.5	40, 45, 50, 50+

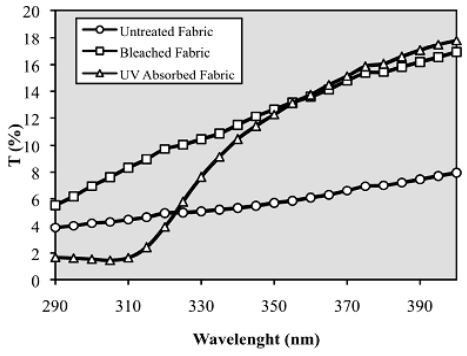


Fig. 2: The spectral transmittance curves of untreated, bleached and 2%UV absorber containing twill 2/1 weave fabrics.

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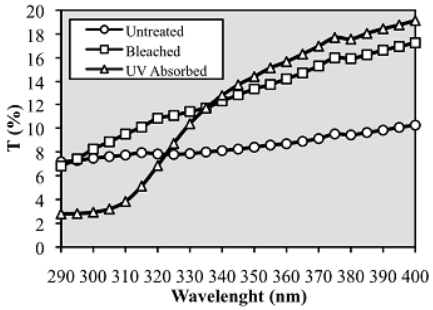
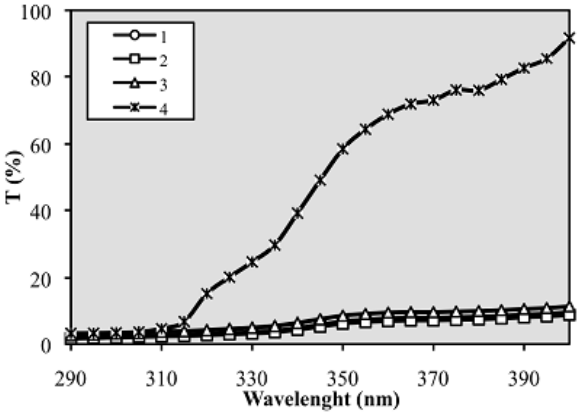


Fig. 3: The spectral transmittance curves of untreated, bleached and 2%UV absorber containing rib 2/1 weave fabrics.

Figure 2 and 3 showed that the % transmission values of UV absorbed fabrics are increased. The UPF values of untreated specimens are higher than those of bleached samples. Impurities present in the untreated samples must have provided some screening effect (Table 3).

Bleached twill fabric has slightly higher UPF compared to bleached rib weave sample. Moreover, the increase in UPF of twill fabric treated with UV absorber is much higher than that of rib weave specimen. This increase might be due to the denser structure of twill fabrics after wet treatments.

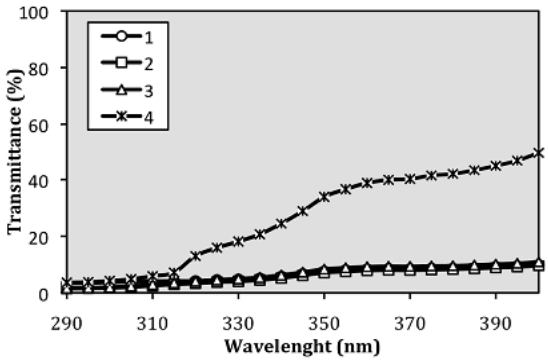


1: dyeing only, 2: UV abs. application before dyeing, 3: UV abs. application during dyeing, 4: UV abs. application after dyeing

Fig. 4: Spectral transmittances of dyed twill 2/1 weave fabrics.

The % transmission values of dyed, UV absorbed before dying, during dyeing and after dyeing fabrics are given Figure 4 and 5, respectively." Before the application of UV absorbers, dyed specimens of twill fabrics have higher UPF values than those of rib fabrics. When both dye and the UV absorber are applied to fabric, effects of their application sequence might worth examining; When UV absorber was applied prior to dyeing, UPF values of both twill and rib weave specimens increased. This increase is higher in the case of rib samples. UPF has increased from 22.01 to 30.03 for rib weave, whereas 31.88 to 34.12 in the case of twill weave specimens.

The Ribs of fabric samples was treated with UV absorbers and dyed simultaneously. This application can also be considered as 'successful' since the UPF values were found more or less the same as in twill fabrics.(Table 4) .In the case of dyeing before the application of UV absorbers, results obtained were completely different. UPF values were even lower for twill weave specimens, and were only slightly higher for rib samples.



1: dyeing only, 2: UV abs. application before dyeing, 3: UV abs. application during dyeing, 4: UV abs. application after dyeing

Fig. 5: Spectral transmittances of dyed rib 2/1 specimens.

The calculated UV protection values of all test specimens are shown in Table 3 and Table 4.

Table 3: The UPF, UVA, UVB values of untreated, bleached and UV absorber containing fabric specimens.

Specimen	Average UPF	UPF ranking	UVA_{AV} (%)	UVB_{AV} (%)
Untreated twill weave fabric	20.80	20	6.15	4.25
Untreated rib weave fabric	12.65	10	8.78	7.53
Bleached twill weave fabric	10.70	10	13.24	7.26
Bleached rib weave fabric	9.60	5	13.92	8.48
Twill weave fabric with 2% UV absorber	25.16	25	12.24	1.72
Rib fabric with 2% UV absorber	15.81	15	14.30	3.45

Table 4: The UPF, UVA, UVB values of dyed specimens.

Specimen	Average UPF	UPF ranking	UVA_{AV} (%)	UVB_{AV} (%)
Dyed and UV absorber-free				
Twill weave fabric	31.83	30	6.39	2.14
Rib weave fabric	22.01	20	7.27	3.73
Appl.of 2% UV absorber prior to dyeing				
Twill weave fabric	34.12	30	5,82	2,08
Rib weave fabric	30.03	30	6.65	2.05
Simultaneous appl. of dye and UV absorber				
Twill weave fabric	22.50	20	8.03	3.27
Rib weave fabric	25.25	25	7.83	2.36
Dyeing followed by appl.of 2% UV absorber				
Twill weave fabric	6.70	5	56.24	4.08
Rib weave fabric	8.71	5	32.60	4.85

Whiteness degrees of twill weave and rib weave fabrics are shown at Figure 6. Figure 7 shows the light fastness values of fabrics.

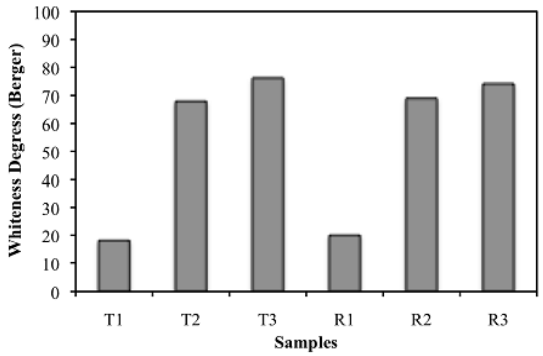
Presence of the UV absorber in white fabric specimens has had no adverse effect on their whiteness values; in fact, a slight increase in whiteness degrees of bleached fabrics has been detected.

Treatment with UV absorber generally improves the light fastness of all fabrics (Figure 7). Different weaving constructions did not affect the light fastness properties of UV applied fabrics. But application of UV absorber before dyeing process is give better results on light fastness properties

The ΔE^* values of the samples represent the color difference. If $\Delta E^* < 1$, the difference between the two color is little and if $\Delta E^* > 1$, the difference is substantial. Figure 8 shows the ΔE values of treated fabrics.

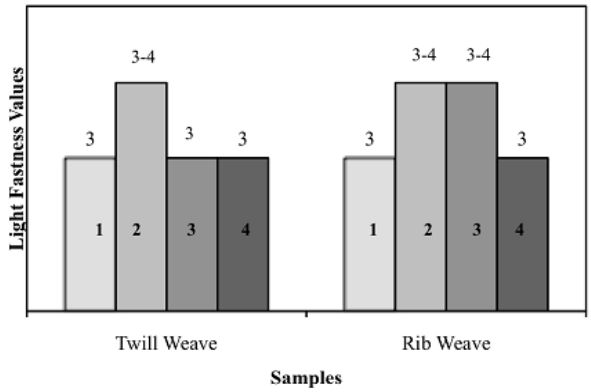
4. Conclusion:

In this study, indicates that clothing can provide an effective barrier to UPF. The results of bleaching and dyeing using the UV absorber has been more better than other fabrics. Different weaving construction evaluating each other, UV absorber is penetrated more effective to the twill weaving structure.



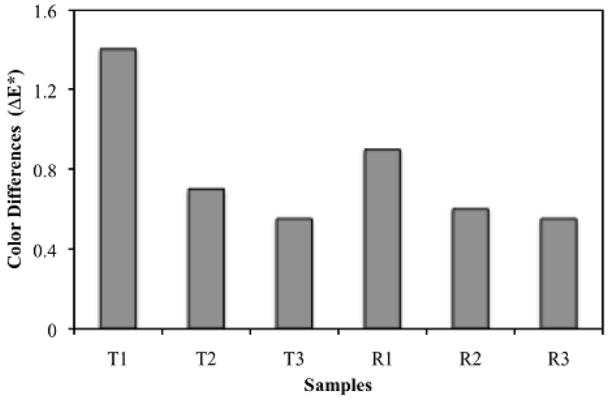
T1: Twill Weave Untreated Sample , T2: Twill Weave Bleached Sample, T3:Twill Weave Bleached Following by Application of UV Absorber in Separate Bath, R1: Rib Weave Untreated Sample , R2: Rib Weave Bleached Sample, R3:Rib Weave Bleached Following by Application of UV Absorber in Separate Bath,

Fig. 6: Whiteness Degrees (Berger).



1: dyeing only, 2: UV abs. application before dyeing, 3: UV abs. application during dyeing , 4: UV abs. application after dyeing

Fig. 7: Comparing Light Fastness Values of Fabrics (ISO 105-B02).



T1:Twill Weave, UV abs. application before dyeing , T2: Twill Weave, UV abs. application during dyeing , T3: Twill Weave UV abs. application after dyeing, R1:Rib Weave, UV abs. application before dyeing , R2: Rib Weave, UV abs. application during dyeing , R3: Rib Weave UV abs. application after dyeing, Standard: dyeing only

Fig. 8: Color Difference Values of Fabrics, ΔE* (D65/10°).

While, twill and rib weaving structure has been not affected the light fastness properties, UV absorber application before dyeing has been increased the whiteness index of the fabrics. In addition, application of the UV absorber in both the fabric structure is not caused the differences in color.

In conclusion, it is evident from this study that for increased protection from UPF, one should choose twill and ribs weave fabrics made from cotton.

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