COTTON FABRIC AND UV-PROTECTION

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Abstract

The harmful effects of UV radiation can be substantially alleviated by wearing heavy weight garments or by using sun creams. However, the use of heavy weight fabrics is unacceptable, due to the resulting increase in skin temperature, which is both uncomfortable and a health hazard. Also, using sun creams is troublesome and subject to failure under many conditions. Therefore, there is a growing demand in the marketplace for textile apparel that offers comfort and protection from UV-A and UV-B radiation. The purpose of this paper is focused on the UV transmission of cotton fabric, the most common textile for summer clothes. This includes the effect of fabric architecture, dyeing and chemical finishing.

Introduction

It is known that ultraviolet (UV) radiation is harmful to human health (Eckhardt et al, 2000; Crews et al, 1999). This radiation is composed of three types: UV-A, UV-B, and UV-C, ranging respectively between 320 nm and 400 nm, 290 nm and 320 nm, 100 nm and 290 nm. UV-C radiation is completely absorbed by the ozone layer, however, the UV-A and UV-B reach the earth's surface and cause serious health problems, particularly skin cancer, sunburn, and photo-aging (Reinert et al, 1997). As results of these growing concerns, special attention was focused by textile researchers on the fabric permeability to the UV radiation in the recent years (Reinert et al, 1997; Eckhardt et al, 2000; Srinivasan et al, 2000). The UV radiation transmitted through a textile fabric consists of the waves that pass unchanged through the pores of the fabric and scattered waves that have interacted with the fabric. Crews et al, 1999 reported that manufacturers of sun protective clothing face a confusing array of information because the published literature contains many contradictory claims. Many research studies were conducted to establish the parameters that affect the UV permeability of the textile garment. Some studies concluded that the compactness and the weight of the fabric are the most relevant parameters, while others claim that dark color shades offer more protection. In the two situations, the garments tend to be less comfortable to wear in hot weather.

This paper is focused on the UV transmission of cotton fabrics, which is the most common textile for summer clothes. We investigated in this preliminary study the effects on the UV permeability of: (1) fabric structure, (2) dyeing with reactive and direct blue, and (3) chemical cross-linking with an UV absorber.

Materials and Methods

Fabric Dyeing

Scoured and bleached woven and knitted cotton fabrics were used in this work for dyeing as well as for chemical cross-linking. The fabrics were dyed using the conventional dyeing method for direct and hot reactive dye. The bath temperature was set at 194°F, the amount of salt was 80g/l, and the quantity of soda ash was 20 g/l. The addition of salts (sodium sulfate and soda ash) to the dye-bath promotes the exhaustion of the dye.

UV Absorber Application

The commercial UV-absorber, rayosan, was applied by the exhaustion method. The concentration of rayosan on the weight of the fiber (wof) was varied between 1 and 10 %. The bath containing fabrics and rayosan was circulated for10 minutes and gradually 70 g/l of sodium sulfate were added. After 10 minutes, the temperature was raised to 194°F. As with the reactive dye, 10 g/l of soda ash were added. The bath was circulated 30 minutes at this temperature. Then the bath was cooled and the fabric rinsed.

Ultraviolet Protection Factor Determination

The ultraviolet protection of a fabric is expressed by the Ultraviolet Protection Factor, UPF. For sun creams, the Sun Protection factor (SPF) is used. The UPF evaluates the reduction in the amount of the UV radiation that passes through the fabric to the skin. For example, when a fabric has an UPF of 20, only 1/20th of UV radiation reaches the skin.

The UPF was measured by the in-vitro method using the SPF-290 Analyzer. This instrument is a recording UV-VIS spectrophotometer designed and optimized for this purpose. The UPF is calculated using the following formula according to the AATCC test Method 183-1999:

$$\mathrm{UPF} = \frac{\sum_{290}^{400} E_\lambda \; S_\lambda}{\sum_{290}^{400} E_\lambda S_\lambda T_\lambda}$$

In this equation, E_λ corresponds to the erythema sensitivity of the average human skin, S_λ is the spectral irradiance of terrestrial sunlight under controlled conditions, T_λ is the transmission spectrum of the garment, λ denotes the wavelength of the UV radiation (290 nm $\le \lambda \le$ 400 nm). The numerator of the above equation describes the quantity of the UV radiation, which reaches the skin if unprotected. The denominator describes the quantity of the UV radiation reaching the skin protected by a garment. The table 1 gives the raking of garments depending on their UV transmission (Shuierer, 1997).

Results and Discussion

UPF of Undyed Woven and Knitted Cotton Fabrics

The table 2 shows the UPF of woven and knitted cotton fabrics along with their thickness (ASTM D1777-96), weight (ASTM D3776-85), and yarn number (ASTM D1059-92).

For the woven fabrics, the UPF increases from 5 (fabric 1) to 9 (fabric 3) when the weight is doubled (from 3.5 to 6.8), the thickness increases from 0.01 to 0.03, and the yarn number decreases from 38 to 10. No significant difference between the UPF of woven 3 and the UPF of knitted fabric is observed even if the fabric thickness and yarn number are different (table 2). This reveals that different types of fabric construction can lead to the same UPF. Consequently, a more detailed investigation is underway in order to establish the relationship between the fabric construction and its UPF in order to engineer the fabric structure for optimal UV protection.

UPF of Dyed Woven Fabrics

Woven fabrics 1 and 2 (table 2) were dyed in blue shade with reactive and direct dyes. The reactive dye was drimarine X-3LR, chlorotriazine type, and the direct dye was direct blue 80. The concentration of the two dyes was varied between 0.03% and 2% on the weight of the fabric. Figure 1 shows the UPF variation of woven cotton fabric dyed with different dye concentration. This figure shows an increase of the UPF with increasing dye concentration; a plateau is reached around 1.5%. In addition, reactive blue X-3LR appears to provide higher UV protection than direct blue 80. The properties of the fabric to be dyed have also an impact on the dye uptake and, therefore, on the UPF. Indeed, for high UV protection performance (UPF ≥ 40), a fabric having fabric 2 properties should be dyed with reactive dye only at 0.3%, while a fabric having fabric 1 properties should be dyed with the same dye at least at 1.3%.

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UPF of Undyed Woven and Knitted
Treated with UV Absorber

The undyed woven 2 and knitted cotton fabrics were cross-linked with a commercial UV absorber, rayosan. Figure 2 shows the evolution of UPF for increasing percentage of rayosan. The non-linear relation shows us that higher is the rayosan concentration higher is the UPF. It also shows that above 8% of rayosan the UPF reaches a plateau. When the percentage of rayosan is greater than 5%, the two treated fabrics provide excellent protection from UV.

Conclusion

In this preliminary study, the UV transmission of cotton fabrics was investigated. Undyed and untreated fabrics (woven or knitted) have high UV transmission and, therefore, little protection. However, when dyed, the dyed fabrics could provide better protection than undyed fabrics. This protection depends on the type of dye, its concentration and the type of fabrics. The chemical cross-linking of undyed fabric with UV-absorber appears to be the best way to increase its UPF and to provide an excellent UV protection.

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References

Crews, P.C., S. Kachman, A. G. Beyer. 1999. Influence on UVR Transmission of Undyed Woven Fabrics, Textile Chemist and Colorist, 31(6) 17-26.

Eckhardt, C., H. Rohwer. 2000. UV Protector for Cotton Fabrics, Textile Chemist and Colorist & American Dyestuff Reporter, 32(4) 21-23.

Reinert, G., F. Fuso, R. Hilfiker, E. Schmidt. 1997. UV-Protecting Properties of Textile Fabrics and their Improvement, Textile Chemist and Colorist, 29(12) 36-43.

Shuierer, M.1997. Practical experience with Solartex products in finishing of sun protection fabrics, Melliand International 3, 168-169.

Srinivasan, M., B.M. Gatewood. 2000. Relationship of Dye Characteristics to UV Protection Provided by Cotton Fabric, Textile Chemist and Colorist & American Dyestuff Reporter, 32(4) 36-43.

Table 1: Ranking of the garments depending on their UV transmission.

UPF	Actual UV transmittance (%)	Category ofprotection
14 – 24	6.7 - 4.1	Good
25 – 39	4.0 - 2.6	Very good
≥ 40	≤ 2.5	Excellent

Table 2: Cotton fabric properties and their UPF.

	UPF	UPF STDV	Weight oz/yd^2	Thickness inch	Yarn number W	Yarn number F
Woven 1	5	0.23	3.5	0.010	38.2	38.9
Woven 2	8	0.15	4.1	0.016	22.8	24.2
Woven 3	9	0.37	6.8	0.030	10.6	10.4
Knitted	10	0.28	6.2	0.022	18.2	

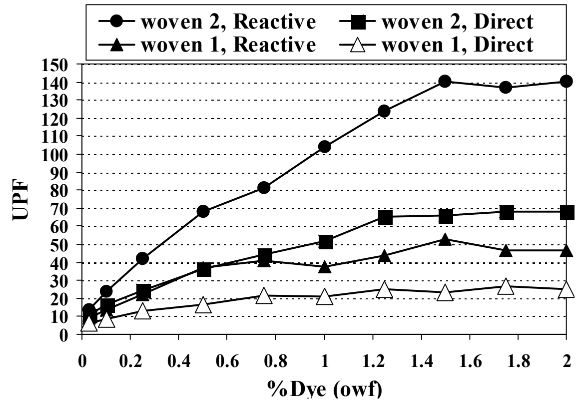

Figure 1: Effect of dye concentration on the UPF of woven fabrics.

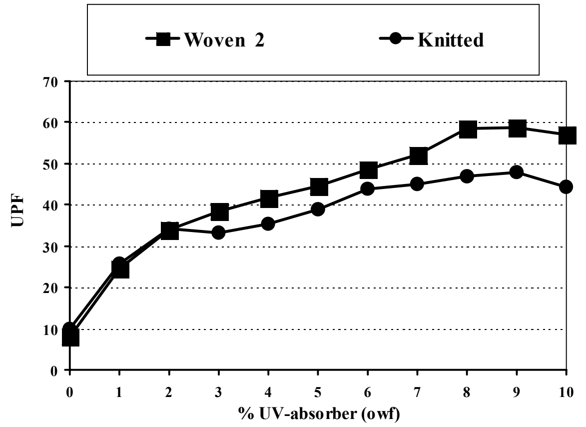

Figure 2: Effect of rayosan on the UPF of woven and knitted fabrics.