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Study The UV-Protection of Dyed Wool with Acid Dyes

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Abstract

Ultraviolet radiation (UVR) from Sunlight damages the skin in the form of sunburns and skin cancer, depending on the exposure time. Sunscreen products application and proper clothing are highly recommended for skin protection from UVR. This study investigated the level of UV protection factor of dyed wool fabrics dyed with different dyes (acid, chromium and metal complex dyes). The results revealed that UV protection factor (UPF) of wool fabrics has increased just a little after dyeing. The UPF is increased from 2.7 to 4.4 for undyed and metal complex dyed samples, respectively.

The other dyed samples have got the UPF as much as Benzophenone, a UV absorber. The amount of UPF displayed that the dyed wool fabrics have got weak UV-protection, and the dyeing has not any significant effect on UV-protection of wool fabric.

Keywords: Wool, Ultraviolet radiation, UV-protection, dye.

1. Introduction

Sunlight carries the fundamental energy for life on earth by driving photosynthesis, but ultraviolet radiation (UVR) from the sun has clear detrimental effects. Short-term exposure to UVR from the sun causes sunburns, and long-term exposure leads to skin cancer [1, 2]. The ultraviolet radiation band consists of three regions: UV-A (320 to 400 nm), UV-B (290 to 320 nm), and UV-C (200 to 290 nm). UV-C is totally absorbed by the atmosphere and does not reach the earth. UV-C is absorbed by the atmosphere and does not reach the earth. UV-A causes a little visible reaction on the skin but decreases the immunological response of skin cells. UV-B is primarily responsible for the development of skin cancer [2, 3]

The most important elements in preventing skin cancer are reducing sun exposure, using sunscreen and wearing appropriate clothing. When UV radiation hits a textile surface, the UV radiation is broken down into several components. Part of the radiation is reflected; another part is absorbed and the last part is transmitted through the fibers and reaches the skin [3,4]. The UV transmittance of the fibers is determined using a

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spectrophotometer; The UV protection factor (UPF) is then calculated from this value. The UVR percentage transmission of a fabric is related to the fabric cover factor by (100-coverage factor) and the UPF is given by UPF= 100/(100-CF) [3,5]. In textiles, UPF is dependent on chemical structure and nature of fibres, moisture content of fibres, fabric construction, density, thickness, porosity, and extension of the fabric, presence of UV absorbers, colour and the finishing given to the fabric [2, 3]. Depending upon the type of dye, the absorptive groups present in the dyestuff, depth after dyeing, the uniformity and additives, the UPF of the textile materials are considerably influenced [3]. Several studies revealed that, dyeing cotton fabrics with natural dyes like Madder, indigo and Cochineal increases the ultraviolet protective abilities of the fabrics. The UPF is further enhanced with colorant of dark hue and high concentration of fabric colorant [2]. Natural dyes such as Rheum and L. erythrorhizon could absorb 80% of the ultraviolet rays and had comparable UV-absorption performance to the common UV-absorber, benzophenone [1]. The substituted benzophenones are effective in protecting wool against yellowing; the maximum protection was obtained from water-soluble UV absorbers, using dye-bath techniques [6]. A ZnO nanohybrid coating on cotton was successfully prepared by in situ polymerization method in miniemulsion. The treated cotton fabrics provided ultrahigh UV protection properties and superior washing fastness, with UPF of >50 even after 50 home launderings [7]. The dyeing of woolen fabrics with madder root, chamomile, pomegranate peel and apple tree branches as natural dyes showed an increase in the UV protection of woolen fabrics. In other studies, the results of dyeing wool fabrics by natural dye extraction from eucalyptus leaves showed that with an increase in dye concentration, UV Protection Factor (UPF) values ranged from very good to excellent for wool fabrics [9].

In this study, wool fabrics were dyed with common dyes. The amount of UV rays transmitted through the dyed wool fabrics was examined based on the color change of the UV-sensitive sample placed under the dyed wool fabric. The color change of the UV sensitive sample depends on the intensity of the UV rays transmitted through the wool fabric, therefore a relationship between color change and UPF is established by measuring the colorimetric data of the sample. It is clear that reducing the fabric cover factor increases the light fade of the UV-sensitive sample [5].

2. **Experimental**

2.1. Materials and method

Knitted wool with a basis weight of 330 g/m2 was used in this study. Various dyes were listed in Table 1 and copper sulfate, aluminum sulfate and potassium dichromate (Merck) were used as mordants for chrome dyes.

Table 1. The name of the used dyes

Dye	Dye class
Imconyl green G	Acid/ Levelling
C.I. acid orange 2	Acid/ Levelling
Imconyl Blue PRL	Acid/ Milling
Imconyl scarlet GFS	Acid/ Milling
Imconyl Navy 5R	Acid/ supermilling
Imconyl Red 200%	Acid/ supermilling
C.I. Acid Red 98	Metal complex 1:1
C.I. Acid Blue 54	Metal complex 1:1
C.I. Acid Red 88	Metal complex 1:2
C.I. Acid Blue 92	Metal complex 1:2
C.I. Mordant Brown 33	Chrome dye
Methylene blue (C.I. Basic Blue 9)	Basic dye

2.2. Dyeing

To study the effect of dyes on UV protection factor (UPF), woolen fabrics were dyed with acid and metal complex dyes (listed in Table 1) by the exhaust process using 1% owf dye at a liquor ratio of 40:1 at boiling temperature for 45 min Excipients for each dye are listed in Table 2.

Table 2. Auxiliaries for dyeing with different dyes

auxiliaries / Dye class	Sulphuric acid (% owf)	Acetic acid (% owf)	Sodium sulphate (% owf)	Ammonium sulphate(% owf)
Acid/ levelling	4	—	20	—
Acid/ milling	—	1.8	10	
Acid/ supermilling	—	—	—	3
Metal complex 1:1	8	—	—	—
Metal complex 1:2	—	—	—	4

For dyeing with mordant dye, wool fabrics were pre-mordanted at boil temperature for 45 min using 3% of different mordants with a liquor ratio of 40:1. The pre-mordant fabrics were dyed using 1% of dye at boil temperature for 45 min. After dyeing for 30 min, 1% of acetic acid was added for maximum exhaustion. As UV sensitive sample, the wool fabric was dyed using dyeing machine H-24M (Co-power Technology Company Ltd., Taiwan) with 0.5% (of) methylene blue dye (M.B. dye) (a basic dye) at 80˚C for 60 minutes that named sensitive sample.

For comparison, benzophenone [6] was selected as a common UV absorber, and a water/ethanol mixture (9/1 v/v) of it was used. The wool fabric was treated with a solution of benzophenone (1 g/L) at 70˚C for 30 min. After treatment, the sample was washed and then air-dried.

2.3. Measurement of UV-protection factor

Each dyed wool fabric was put on a sensitive sample, and all were exposed to UV light (40 W) for 43 hours. Also, a sensitive sample without cover and another sensitive sample covered completely with an opaque material, was exposed to UV light. Then the reflectance (R) of the under samples was measured by reflectance spectrophotometer (X-rite, Color-Eye 7000A) at the maximum absorbance wavelength of a sensitive sample (650 nm).

The photofading of the sensitive sample is increased by decreasing the fabric cover factor. Based on the partitive colour mixing law and the relationship between UPF and cover factor (CF), the UPF of the dyed sample was calculated by using Equation (1) [5]:

$$UPF= (R(\lambda)_C - R(\lambda)_{UC}) / (R(\lambda)_C - R(\lambda)_S) \qquad (1)$$

Where R(λ)S is the reflectance of the sample of dyed wool fabric, R(λ)C and R(λ)UC are the reflectance of sensitive samples completely covered and without cover, respectively.

3. Results and discussion

The reflectance of the sensitive samples (the samples dyed with methylene blue) after exposing to UV light are shown in Table 3. The reflectance of methylene blue dyed wool fabric (sensitive sample) without cover (R(λ)UC) and with complete cover (R(λ)C) are 4.992 and 1.691, respectively.

Table 3. The reflectance of methylene blue dyed (sensitive) samples that put under dyed wool fabrics after exposing to UV light

Dye or other Index for wool fabric	Reflectance of sensitive (under) sample
Acid levelling green	851.2
Acid levelling orange	613.2
Acid milling Blue	067.3
Acid milling scarlet	713.2
Acid supermilling Navy	945.2
Acid supermilling Red	213.3
Metal complex 1:1 Red	437.2
Metal complex 1:1 Blue	847.2
Metal complex 1:2 Red	469.2
Metal complex 1:2 Blue	629.2
Mordant Brown + copper sulphate	654.2
Mordant Brown + dichromate	225.3
benzophenone	626.2
—	908.2

The UPF of dyed samples was calculated based on the reflectance of the sensitive sample listed in table 3 and equation 1. The UPF values are shown in Table 4. Table 4 shows that the maximum and minimum UPF belong to red metal complex 1:1 and mordant dye with dichromate pre-mordanted, respectively. The UPF of undyed wool fabric is 2.71 and has increased after dyeing with different dyes just less than two times (4.43 for metal complex dye). It means the dyes cause just a little increase in the UV protection factor. The red metal complex dyes have the most UV protection factor, even more than benzophenone as a UV absorber. The results display that color of the dyes has influenced UPF so that the colors with a wavelength near to red color have a higher UV protection factor in each class of used dyes except super-milling acid dyes.

Using Cu mordant in dyeing with the chrome dye has improved the UPF more than Cr mordant and as much as red color. As compared to the undyed sample, Cr mordant has led to a decrease in UPF and the red super-milling dye.

Some dyes, such as leveling (orange), milling (red), and metal complex 1:2 (blue), have got the UPF as much as benzophenone. Therefore, one can use these dyes instead of benzophenone as a UV absorber in dyed clothes. However, the dyes used did not significantly affect the UV protection factor, as the UPF value of 20-29 for textiles offers good protection and the UPF value above 40 offers excellent protection [3] Since UV light is the primary cause of the fading of practically all dyes, the weakening of fibers and fabrics, and the photodegradation of many other substances [6]. Color difference (ΔE) can explain which dye resists UV rays and has a good light fastness after exposure to UV light.

Table 4. The UPF of dyed and undyed wool fabric as well as benzophenone treated wool fabric

Wool fabric treated with	UPF
Acid levelling green	2.85
Acid levelling orange	3.58
Acid milling Blue	2.39
Acid milling scarlet	3.23
Acid supermilling Navy	2.63
Acid supermilling Red	2.17
Metal complex 1:1 Red	4.43
Metal complex 1:1 Blue	2.86
Metal complex 1:2 Red	4.24
Metal complex 1:2 Blue	3.52
Mordant Brown + copper sulphate	3.43
Mordant Brown + dichromate	2.15
Benzophenone	3.53
—	2.71

Table 5. The color difference of treated wool fabric after expos 43 hours of UV exposure

Wool fabric treated with	ΔE
Acid levelling green	3.01
Acid levelling orange	2.51
Acid milling Blue	12.99
Acid milling scarlet	6.24
Acid supermilling Navy	4.28
Acid supermilling Red	2.71
Metal complex 1:1 Red	7.20
Metal complex 1:1 Blue	3.80
Metal complex 1:2 Red	2.20
Metal complex 1:2 Blue	4.12
Mordant Brown + copper sulphate	2.42
Mordant Brown + dichromate	4.87
benzophenone	12.40
—	6.23

Table 5 displays the color difference of dyed wool fabrics after exposure to UV lights which demonstrates the minimum color difference is related to the red metal complex 1:2. The dye has a good UV-light fastness and a high UPF compared to the other dyes. Orange leveling, copper mordant, and red super-milling dyes present a low color difference, but benzophenone and blue milling dyes show a high color difference. Although in some dyes the higher UPF gives the lower color difference (higher light fastness), there isn't a relation between the UPF and the ΔE. For example, benzophenone has resulted in a high UPF in wool fabric but the color difference of the wool fabric treated with benzophenone is high that is the light fastness of treated wool is poor.

4. Conclusion

In this study, wool fabrics were dyed with common dyes. The amount of UV rays transmitted through the dyed wool fabrics was examined based on the color change of the UV-sensitive sample placed under the dyed wool fabric. The color alteration of the UV-sensitive sample depends on the intensity of the transmitted UV rays through the wool fabric. The photofading of the UV-sensitive sample is increased by decreasing the fabric cover factor.

The results demonstrated that some of the common dyes suitable for wool fabrics have slightly increased UV protection factor of wool fabrics. The UPF is increased from 2.7 to 4.4 for undyed and metal complex dyed samples, respectively. The color of the dyes has influenced UPF, so the red dyes have higher UPF than blue dyes, which is as much as the UPF of benzophenone as a UV absorber.

References

[1] Feng, X.X.; et al: New Insights into Solar UV-protective Properties of Natural Dye, *Journal of Cleaner Production*, **15** (2007), pp. 366-372.

[2] Sarkar, A.K.: An Evaluation of UV Protection Imparted by Cotton Fabrics Dyed with Natural Colorants, *BMC Dermatology*,**4** (2004) 15, pp. 1-8.

[3] Saravanan, D: UV Protection Textile Materials, *AUTEX Research Journal*, **7** (2007) 1, pp. 53-62.

[4] Hoffmann, K.; et al: In Vitro and In Vivo Determination of the UV Protection Factor for Lightweight Cotton and Viscose Summer Fabrics: A Preliminary Study, *J Am Acad Dermatol*, **43** (2000) 6, pp. 1009-1016.

[5] Amirshahi, S.H.: A New Technique for Determination of Sun Protection Factor in Textiles, *Journal of Science and Technology of Polymer*, **9** (1996) 4, pp. 241-247.

[6] Cristea, D; Vilarem, G: Improving Light Fastnesss of Natural Dyes on Cotton Yarn, *Dyes and Pigments*, **70** (2006), pp. 238-245.

[7] Lu, H.; et al: Fabrication of UV-blocking Nanohybrid Coating via Miniemulsion Polymerization, *Journal of Colloid and Interface science*, **300** (2006), pp. 111-116.

[8] Mansour, R.; et al.: UV Protection and Dyeing Properties of Wool Fabrics Dyed with Aqueous Extracts of Madder Roots, Chamomiles, Pomegranate Peels, and Apple Tree Branches Barks, Journal of Natural Fibers, 19 (2) (2022), pp. 610-620.

[9] Mongkholrattanasit, R., et al., An Evaluation of UV Protection Imparted by Wool Fabric Dyed with Natural Dye from Eucalyptus Leaf, Chiang Mai journal of Science, 41(5) (2014), pp.1208-1219.