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UV PROTECTION WITH ZEOLITE TREATED COTTON KNITTED FABRIC - THE INFLUENCE OF YARN LINEAR DENSITY

BY
*Ana Marija GRANCARIĆ, **Anita TARBUK and ***Lea MARKOVIĆ

Abstract. UV radiation (UV-R) can be divided into UV-A, UV-B and UV-C radiation. UV-C radiation get absorbed by atmosphere, but diminishing of the ozone layer results with the reaching of UV-B and UV-A rays on the Earth's surface. Even though the UV-A rays are necessary for vitamin D synthesis, longer exposure to UV-A and UV-B rays can cause acute and chronic reactions and damages such as erythema (sunburn), sun tanning, photocarcinogenesis and "photoaging", as well as known skin aging and recently the formation of skin malignant neoplasm. Garment provides some UV protection, but in most cases there are not enough its sun screening properties. This protection, among other large number of factors, highly depends on fabric surface and construction, especially for longer pending in the sun. Therefore, in last few years different protective finishes and material modification were developed. This paper deals with the influence of yarn linear density of cotton knitted fabric on its ultraviolet skin protection expressed as ultraviolet protection factor (UPF). The effects of yarn linear density on UPF using knitted fabrics from the same cotton fibers were discussed. Raw, pretreated and zeolite treated cotton fabrics were used. UV-A and UV-B transmissions were measured on transmission spectrophotometer Cary 50 Solarscreen (Varian) according to AATCC Test Method 183-2000. On the base of these values Ultraviolet protection factor (UPF) was calculated.

Keywords: cotton knitted fabrics, yarn linear density, zeolite treatment, UV protection

1. Introduction

Materials for human performance, such are medical, protective and sports, is one of nine themes according the European Technology Platform for the Future of Textiles. As the textile and clothing are person's second skin, it is the most suitable interface between environment and human body and ideal tool for personal protection and safety [1].

UV radiation (UV-R) can be divided into UV-A (from 400 to 320 nm), UV-B (from 320 to 280 nm) and UV-C (under 280 nm) radiation. UV-C radiation gets absorbed by atmosphere, but diminishing of the ozone layer results with the reaching of UV-B and UV-A rays on the Earth's surface. Even though the UV-A rays are necessary for vitamin D synthesis, longer exposure to

UV-A and UV-B rays can cause acute and chronic reactions and damages such as erythema (sunburn), sun tanning, photocarcinogenesis and "photoaging", skin aging and recently the formation of skin malignant neoplasm [2-4].

Garment provides some UV protection. Fabric can reflect, absorb and scatter solar wavelengths, but in the most cases it does not provide full sun screening properties. This protection, among other large number of factors such are type of fiber, porosity, density, moisture content, type and concentration of dye and FWA in the case of white textiles, and on UV-B protective agents, if applied [2-7], highly depends on fabric surface and construction.

Natural zeolites are crystalline aluminosilicates with unique adsorption, cation exchange, and catalytic properties that have multiple uses in industry and agriculture. It can absorb, but mostly scatter the UV-R [6,7]. Zeolites have also been investigated in a broad spectrum of medical uses; such are tumor and diabetes mellitus. Due to its cation exchange ability zeolites were used in water purification and in detergents for longer time period [8-10].

Clinoptilolite (TMAZ) is a natural zeolite with enhanced physicochemical properties. It has a cage-like structure (Figure 1) consisting of high portion of SiO_2 (60-67 %). It was produced by tribomechanical processing in the patented machine.

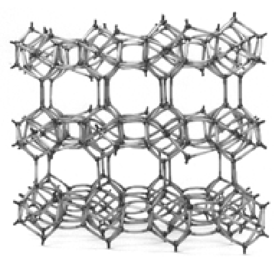

Fig. 1 - Structure of Clinoptilolite

When applied externally in powder form, it quicken the healing of wounds and surgical incisions. It is proven bactericides and fungicides as well [8]. Therefore, in this paper nanoparticles of natural zeolite (clinoptilolite) were applied by different treatments on cotton knitted fabric for achieving higher UV protection.

2. Experimental

The fabric used was a circular weft knitted fabric of 100 % raw cotton yarn of different yarn linear density – 17 tex, 20 tex and 25 tex. Fabrics were mercerized and zeolite treated. Mercerization was performed in bath containing 24 % NaOH, 8 g/l anionic surfactant Subitol MLF (Bezema) in a liquor ratio 1:25, 2 min, at 18 °C. Samples were rinsed and neutralized. 5 g/l of zeolite nanoparticles were applied to raw cotton fabric before, after and during mercerization process. Labels and treatments are given in Table 1.

Table1

Fabric labels and treatments

Label			Treatment
17R	20 R	25 R	Raw (17 tex, 20 tex, 25 tex)
17RM	20RM	25RM	Raw mercerized (17 tex, 20 tex, 25 tex)
17RZ	20RZ	25RZ	Raw impregnated with zeolite (17 tex, 20 tex, 25 tex)
17RMZ	20RMZ	25RMZ	Raw mercerized, impregnated with zeolite (17 tex, 20 tex, 25 tex)
17RZM	20RZM	25RZM	Raw, zeolite added during mercerization (17 tex, 20 tex, 25 tex)

Since this paper deals with the influence of yarn linear density of cotton knitted fabric on its UV protection which depends on fabric porosity, mechanical properties were studied as well. Fabric mass per unit area was determined according to ISO 3801:1977 *Textiles - Woven fabrics - Determination of mass per unit length and mass per unit area*. Fabric shrinking after treatments was determined with numbering whales and courses per 10 cm according to ISO 4921:2000 *Knitting - Basic concepts – Vocabulary*.

Remission spectrophotometer SF 600 PLUS CT (Datacolor) was used for measuring CIE whiteness and Yellowing Index according to DIN 6167 *Description of yellowing of practically white or practically colourless materials*.

UV-A and UV-B transmissions were measured on transmission spectrophotometer Cary 50 Solarscreen (Varian) according to AATCC Test Method 183-2000 *Transmittance or Blocking of Erythemally Weighted Ultraviolet Radiation through Fabrics*. On the base of these values Ultraviolet protection factor (UPF) was calculated according to:

$$\mathrm{UPF} = \frac{\sum_{280}^{400} E(\lambda)\cdot S(\lambda)\cdot \Delta\lambda}{\sum_{280}^{400} E(\lambda)\cdot S(\lambda)\cdot \tau(\lambda)\cdot \Delta\lambda} \tag{1}$$

Where:

$E(\lambda)$ = relative erythemal spectral effectiveness

$S(\lambda)$ = solar spectral irradiation [W m^{-2} nm^{-1}]

$\tau(\lambda)$ = average spectral transmittance through specimen

$\Delta\lambda$ = measured wavelength interval [nm]

Ultraviolet protection factor, UPF values indicate the ability of fabrics to protect the skin against sun burning. It indicates how much longer a person can stay in the sun with the fabric covering the skin as compared with the uncovered skin to obtain same erythemal response.

3. Results and discussion

The paper investigates the influence of yarn linear density and treatment with nanoparticles of natural zeolite (clinoptilolite) to cotton knitted fabric UV protection.

It is well known that the fabrics treated in wet conditions like water and alkaline conditions undergo some structural changes reflected in lower porosity. Therefore, surface mass per unit area (m) and number of whales (r) and courses (n) were determined. Results are presented in Table 2.

Table 2

Surface mass per unit area (m) and number of whales (r) and courses (n) of cotton knitted fabrics

Fabric	m [g/m^2]			r [wale/cm]			n [course/cm]		
	17tex	20tex	25tex	17tex	20tex	25tex	17tex	20tex	25tex
R	80	100	131	11	11	11,5	12,5	14	15
RM	180	189	250	14	14	14,5	16,5	17,5	18
RZ	81	105	138	12,5	12,5	13	14,5	15,5	16
RMZ	160	190	227	14,5	14,5	15	18,5	20	20,5
RZM	154	192	220	14	14	14,5	20	22	22,5

It is evident that in every wet treatment cotton swells what leads to shrinkage of fabric. Shrinkage of knitted fabric in wet condition is affected by stresses accumulated during the production so that relaxation in wet conditions is inevitable. Zeolite treatments result in only small shrinkage regardless of yarn linear density. Meanwhile, mercerization process resulted in high shrinkage due to fiber swelling and structure change. It is confirmed in high mass increment for almost 90 % and increment of whales and courses per cm of cotton knit fabric (Table 2). This phenomenon is most expressed on cotton knitted fabric of yarn linear density 17 tex, because there was more free space for swelling.

Spectral characteristics of cotton knitted fabrics were measured using spectrophotometer Datacolor SF 600 PLUS CT. CIE whiteness (W_{CIE}) and yellowness index (YI) were calculated automatically (Table 3).

Table 3

CIE whiteness (WH) and yellowness index (YI) of cotton knitted fabrics

Fabric	W_{CIE}			YI		
	17tex	20tex	25tex	17tex	20tex	25tex
R	14,6	9,0	5,8	22,9	23,8	25,3
RM	25,2	23,8	21,9	19,9	19,7	20,5
RZ	14,1	18,9	16,0	23,2	21,6	22,5
RMZ	19,6	18,5	15,8	21,4	21,4	67,6
RZM	23,5	21,1	14,3	20,3	20,6	67,9

Raw cotton contains different impurities such are waxes, protein substances, pectin and other that give the cotton knitted fabric yellowish staining. This phenomenon is the most evident on raw cotton fabric of yarn linear density 25 tex. During alkali treatment, like mercerization, some impurities are getting removed what leads to cotton whitening. Therefore, CIE whiteness of mercerized cotton fabrics is a little bit higher than whiteness of raw one. Natural zeolites are yellowish, therefore small lost of fabric whiteness and small yellowing occurs. Analogue to whiteness increment, yellowing index decreases.

The effects of yarn linear density and zeolite treatment of cotton knitted fabric on its ultraviolet skin protection is expressed as ultraviolet protection factor (UPF). Mean UPF, UV-A and UV-B transmissions were measured on transmission spectrophotometer Cary 50 Solarscreen (Varian) according to AATCC Test Method 183-2000. Results are collected in Table 4.

Table 4

Mean UPF, UV-A and UV-B transmission, UPF rating and UV protection of cotton knitted fabrics

Fabric	Mean UPF			τ_{UVA}			τ_{UVB}		
	17tex	20tex	25tex	17tex	20tex	25tex	17tex	20tex	25tex
R	3.918	8.852	10.211	26.519	14.232	11.844	24.691	11.768	8.451
RM	13.593	18.231	25.273	8.137	8.201	6,703	4.114	4.512	2,911
RZ	13.698	24.045	27.514	9.402	6.157	5.462	6.535	3.559	3.108
RMZ	24.429	50.264	85.078	6.854	3.954	2.898	3.051	1.446	0.730
RZM	23.734	30.778	76.168	6.997	5.837	3.224	3.323	2.439	3.804

Pectine and waxes in raw cotton absorb small quantities of UV radiation; therefore raw fabric has small sun screening properties but for UV protection it is still non-rateable. In mercerization fabric highly shrunk what have resulted in weaker UV-A and UV-B transmission of UV-R through a more tightly knitted fabric. Therefore, UV protection of mercerized cotton is good regardless the yarn linear density (Table 4). Natural zeolite addition to the bath increases significantly UV protection, regardless the applying method. It scatters the UV-R resulting in lower UV-A and UV-B transmission. Zeolite treated cotton fabric of yarn linear density 17 tex gives off good protection and other fabrics give very good UV protection. If applied after or during the mercerization process, synergistic effect occurs. This phenomenon is more explicit for the fabric treated with natural zeolite after mercerization, because more zeolite nanoparticles remain on fabric surface and light scattering is higher. Therefore, fabric of higher yarn linear density, 20 and 25 tex, give off excellent UV protection. Form the Table 4 it is evident that fabric yarn linear density increment results in higher UV protection regardless of treatment.

4. Conclusion

Every wet treatment of cotton fabric leads to fabric shrinkage and surface mass increment.

Raw cotton contains different impurities which give it yellowish staining. Mercerization leads to cotton whitening. Small lost in fabric whiteness occurs in treatment with natural zeolites. Analogue to whiteness increment, yellowing index decreases.

Knitted cotton fabric yarn linear density increment results in higher UV protection regardless of fabric treatment. Raw cotton fabric contains pectine and waxes that give it small sun screening properties. Mercerization result in weaker UV-A and UV-B transmission, what leads to good UV protection.

Natural zeolite treatment increases significantly UV protection, regardless the applying method. It scatters the UV-R resulting in lower UV-A and UV-B transmission. If applied after or during the mercerization process, synergistic effect occurs.

*University of Zagreb, Faculty of Textile Technology, Department of Textile Chemistry and Ecology, Prilaz baruna Filipovića 30, HR-10000 Zagreb, Croatia.

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