ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

THE INFLUENCE OF TEXTILE FINISHING TECHNOLOGY ON UPF

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Abstract: *The main goal of the study was to develop an ecological and comfortable textiles for summer clothes with increased Ultraviolet Protection Factor (UPF>50+) able to protect human body from harmful effects of UV rays. The identification of critical parameters to create new fabric structures, manufacturing of weaving and knitting samples, evaluation of the textile characteristics and optimization of dyeing and finishing technologies with setting of an efficient, cost-effective and eco-friendly method to enable really industrial dyeing and development of UV protective textile materials for summer clothes, sportswear and leisure equipment were took into consideration. New innovative aspects such as a new approach to produce comfortable UV shielding fabrics with UPF > +50 by engineering innovative structured textiles surfaces, combining natural selected dyes and modified nanoclays leading to high UV rays reflection and increased use of renewable resources (natural dyes) and safe natural minerals (clays) with high impact on human health and environment (avoidance of the substances excluded by eco-labels and the REACH SVHC candidate list) were envisaged. The paper presents the level of UPF obtained by using 100% viscose material treated with Nanomer I.31PS, Nanomer clay and Nanomer I.28 E, Nanomer clay.*

Key words: *ultraviolet protection factor, UV rays, protective textiles, comfortable.*

1. INTRODUCTION

According to WHO, 2-3 million non-melanoma skin cancers and 132000 melanoma skin cancers occur globally each year, the UV radiations contributing to 50%-90% of skin cancer and affecting especially the vulnerable category of children and adolescents. UV protective clothes represent one of the easiest and powerful solutions to avoid the negative effects of UV rays (cancer, DNA mutations, immune system damage, skin aging) and to improve the human health.

Despite multiple attempts to create protective textiles against the destructive effects of UV rays (UV absorbers, dyeing, design of tightly fabric structures) the results are not successful due to the multiple limitations of the current approaches: the reduced range of colors able to provide a high Ultraviolet Protection Factor (UPF>50 +)[1, 2]; the inability of textiles to ensure a comfort for hot and humid climate (generally, the UV protective textiles are heavy, have tight construction, low air/water permeability, low thermal transfer, high accumulation of static electricity)[3, 4]; the reduced use of natural yarns (most of UV protective fabrics are made in synthetic yarns); the rapid discoloration of the dyes under solar light, ozone, temperature, humidity, pollutants; use of toxic compounds (e.g. UV absorbers) to increase the solar protection [5, 6].

Many attempts were performed to create protective textiles against the destructive effects of UV rays: treatment with UV absorbers able to convert electronic excitation energy into thermal energy, acting as radical scavengers and singlet oxygen quenchers; inclusion into fibers or as finishes of metal oxide nano particles (TiO_2, ZnO) but used in low quantity, they have no effect on UV rays absorption and, used in large quantities, impair the textile properties and act as photocatalysts, degradating textiles; dyeing with different types of dyes: some dyes or pigments absorbs in UV increasing the UPF of textiles;design of tightly fabric structure: UV protection is strongly related to the fibres physico-chemical properties, presence of UV absorbers, construction, thickness, porosity, stretch, moisture content, color and the finishing of the fabrics.

2. MATERIALS AND METHODS

For the finishing with hybrid ceramic nanocomposites, we produced knitted fabrics whose characteristics are shown in table 1. The fabrics dyed with the reactive dye Red S-3B indicates an insufficient sun protection factor for the protection of the human body (UPF=5).

Table 1: *The characteristics of the knitted fabrics*

No.	Characteristics/ Sample	Unit	Sample no. 1	Sample no. 2	Sample no. 3
1	Colour	-	white		
2	Composition	-	100% viscose	100% viscose 1% Red S-3B	100% viscose 4% Red S-3B
3	Structure	-	Single jersey	Single jersey	Single jersey
4	Mass	g/m^2	234	232	237
5	Thickness	mm	0,784	0,81	0,824
6	Wales Density	wales/10cm	128.5	122.5	128,0
7	Courses Density	courses/10cm	120,0	130,0	128,0
8	Bursting and Deformation Strength	Kpa	262.0	290.1	287.3
		mm	34.9	43.6	38.1
9	Water Vapor Permeability	%	38.1	43.0	33.0
10	Air Permeability	$l/m^2/sec.$	1670	1350	1284
11	Abrasion Resistance	no. of rubs	>5 000	> 5 000	> 5 000
12	Surface Resistivity	$\Omega cm \times 10^{13}$	3.72	4.49	4.22
13	Volume Resistivity	$\Omega cm \times 10^{14}$	2.46	2.15	6.13
14	Thermal Resistance	$m^2 \times K/W$	0.0306	0.0257	0.0274

The following nanoceramic composites were used for the experimentations:

- montmorillonite, Na-MMT: cation exchange capacity (CEC)/ Modifier Concentration: 97 meq/ 100g; d-spacing: 12.61 Å;

- Nanomer I.28E, a modified surface nanoclay containing 25-30% trimethyl stearyl ammonium, Sigma-Aldrich, USA;

- Nanomer I.31Ps, a montmorillonite whose surface is modified with 15-35% octadecylamine and 0.5-5% aminopropyltriethoxysilane, Sigma Aldrich, USA.

The inclusion of large organic cations such as octadecyl trimethylammonium bromide changes the properties of the montmorillonite from hydrophilic to hydrophobic/ lipophilic.

The following experiments were carried out:

Experiment 1: The sodium montmorillonite dispersion (Na-MMT) was prepared by introducing the powder gradually with strong stirring in the water so as to obtain 1 g/l concentration.

Experiment 2: A solution containing 1.018 g/L Imerol JSF (anionic surfactant) and 0.262 g/l

Brij L23 (tricosethylene glycol dodecyl ether, polyoxyethylene (23) lauryl ether, Sigma, Germany) was prepared. It was heated to 40°C for Brij L23 dissolution. The powder of I.28E nanomer was gradually added with strong stirring, to obtain the final concentration of 1.024 g/l.

Experiment 3: A solution containing 2.076 g/l Imerol JSF and 1 g/l Brij was prepared. It was heated to 40°C for Brij L23 dissolution. The powder of I.28E nanomer was gradually added with strong stirring to obtain 2.036 g/l concentration.

Experiment 4: A solution containing 1 g/l Imerol JSF and 0.25 g/l Brij L23 at 40°C for Brij L23 dissolution was prepared. The powder of I31PS nanomer was gradually added with strong stirring to obtain 1 g/l concentration.

Experiment 5: A solution containing 1 g/l Imerol JSF and 0.25 g/l Brij L23 at 40°C for Brij L23 dissolution was prepared. The powder of I31PS nanomer was gradually added with strong stirring to obtain 2 g/l concentration.

3. RESULTS AND DISCUSSION

The UPF protection factor was determined using Varian Cary 50 Agilent UV-VIS equipment and the results are shown in Table 2.

The innovative design of the Cary 50, which incorporates a Xenon flash lamp, enables it to offer many advantages over traditional UV-Vis spectrophotometers.

The Cary 50 is controlled by the new Cary WinUV software. This Windows based software features a modular design which makes it easy to use.

Table 2: *UPF protection values*

Experiment	Sample notation	Components	UPF with filter UG11	Evolution from the original	UPF without filter UG11	Evolution from the original
Exp. 1	1.1E1	100% viscose + 1g/l Na-MMT	5	5	10	5
	1.2.1E1	100% viscose + 1% Red S-3B + 1g/l Na-MMT	10	5	30	20
	1.2E1	100% viscose + 4% Red S-3B + 1g/l Na-MMT	30	25	50+	40+
Exp. 2	1.1E2	100% viscose + 1g/l I-28E	5	5	5	0
	1.2.1E2	100% viscose + 1% Red S-3B + 1g/l I-28E	25	20	45	35
	1.2E2	100% viscose + 4% Red S-3B + 1g/l I-28E	25	20	50+	40+
Exp. 3	1.1E3	100% viscose + 2g/l I-28E	0	0	10	5
	1.2.1E3	100% viscose + 1% Red S-3B + 2g/l I-28E	25	20	50+	40+
	1.2E3	100% viscose + 4% Red S-3B + 2g/l I-28E	20	15	50^{+}	40
Exp.4	1.1E4	100% viscose + 1g/l I-31PS	10	10	15	10
	1.2.1E4	100% viscose + 1% Red S-3B + 1g/l I-31PS	45	40	35	25
	1.2E4	100% viscose + 4% Red S-3B + 1g/l I-31PS	50+	40+	50	40
Exp. 5	1.1E5	100% viscose + 2g/l I-31PS	5	5	10	5

	1.2.1E5	100% viscose + 1% Red S-3B + 2g/l I-31PS	30	25	15	5
	1.2E5	100% viscose + 4% Red S-3B + 2g/l I-31PS	50+	40+	50+	40+

In Figures no. 1-5 is presented the evolution of UPF within the experimental schemes 1-5. By analyzing these figures, the following aspects results:

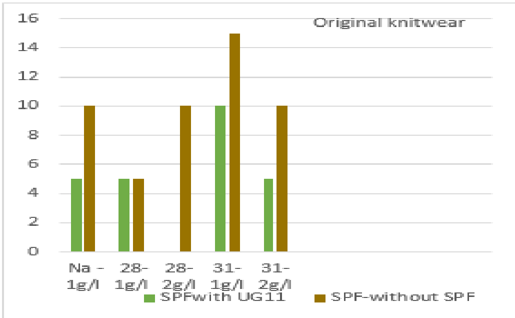

Fig. 1: *UPF for original fabric*

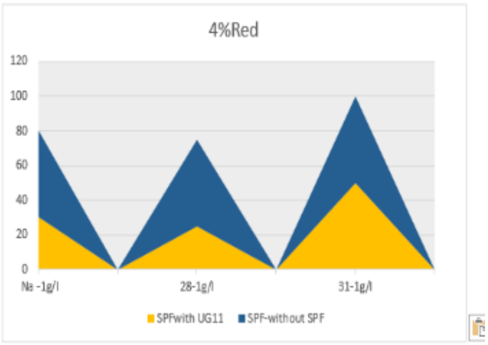

Fig. 2: *UPF for 1% Red+1g/l NP*

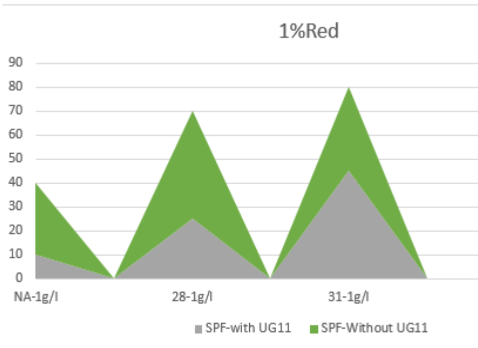

Fig. 3: *UPF for 4% Red + 1g/l NP*

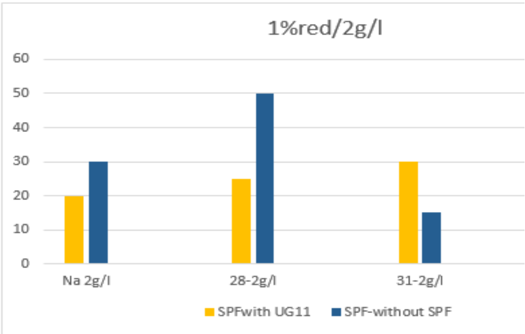

Fig. 4: *UPF for 1% Red + 2 g/l NP*

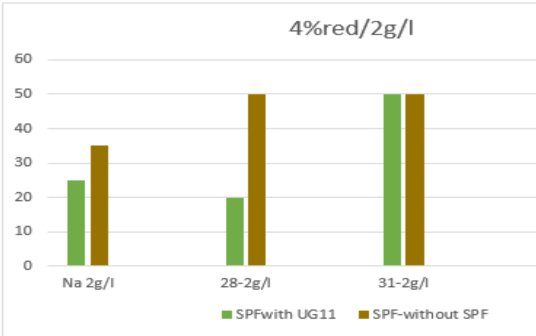

Fig. 5: *UPF for 4% Red + 2 g/l NP*

The UPF values were evaluated according to the Australian/ New Zealand standard (AS/ NZS 4399-1996), for the ultraviolet spectral range with a wavelength of 290-400 nm using the Varian spectrophotometer equipped with an integrated sphere accessory and a support for fabrics. For each sample, UPF is calculated according to the following equation:

$$UPFi = \Sigma E\lambda S\lambda \Delta\lambda / \Sigma\ E\lambda S\lambda T\lambda \Delta\lambda \quad \textbf{(1)}$$

where E is CIE relative spectral efficiency; S is the solar spectral radiation; T is the spectral transmission of the fabric; $\Delta\lambda$ is the difference of the wavelengths expressed in nm and λ is the wavelength expressed in nm.

The assessed UPF of the sample is calculated by introducing a statistical correction. Starting from the standard deviation of the UPF average, the standard error of the UPF average is calculated for a 99% confidence level. The UPF rating will be the UPF average minus the standard error, rounded to the nearest multiple of 5. According to the Australian classification scheme, the textiles can be considered as providing a good, very good and excellent protection if the UPF ranges from 15 to 24, 25 to 39 and, respectively, more than 40. For the UPF rating of 55 or higher, the term 50+ is used.

4. CONCLUSIONS

- The treatment experiments of the knitted fabrics made of 100% white and dyed viscose (with 1% and 4% RED S-3B dye) were made using 3 types of Nanomers: Na-MMT, Nanomer I.28E, Nanomer I.31PS in different concentrations 1 g/l and 2 g/l).

- The best of UPF values were obtained for the fabrics made of 100% dyed viscose with 1% or 4% Red S-3B dye and treated with Nanomer I31PS for both 1g/l and 2 g/l concentration.
- Experiments will continue for knitted and woven fabrics made of 100% cotton, 100% polyester and cotton/ polyester blending.

ACKNOWLEDGEMENTS

This work was carried out in the project: "Proiectarea si dezvoltarea materialelor cu protectie UV - UV-Shield", derulat in European and International Cooperation Program - Subprogramme 3.5 - Alte initiative si programe europene si internationale - EUREKA Traditional Project, EUREKA-Cluster, Eurostars, implemented with the support of Ministry of Research and Innovation, project no.55/2017, Eureka Number E!10710.

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