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EDA MODIFIED POLYESTER FABRIC FOR BETTER UV PROTECTION

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ABSTRACT
The new textile application for achieving the materials for human performance (medical, protective and sports) is one of the guidance for future textile development in Europe. The present paper is an attempt to modify surface of polyester fabric with EDA (ethylenediamine) for achieving better UV protection. Polyester fabric protective ability from UV radiation (UV-R) was investigated after EDA and UV absorber treatment and optical brightening. Polyester fabrics of poly(ethylene-terphtalate) for summer clothing purpose was treated in EDA. Optical brightener Uvitex ERN-P (Ciba) was applied on polyester fabric surface by thermosol and UV absorber, Tinofast PES (Ciba) commercial product specially produced for UV protection in exhaustion method. UV protection was determined using transmission spectrophotometer Cary 50 (Varian) according to AS/NZS 4399:1996; fabric whiteness (CIE whiteness, CIE_{WH}) and yellowness (Yellow Index, YI) was determined using remission spectrophotometer SF 600 PLUS CT (Datacolor) according to DIN 6167:1980. For durability of treatment fabrics were washed according to ISO 6330:2000.
Keywords: PET fabric, surface modification, EDA, UV protection

1. INTRODUCTION
Alkaline hydrolyses of polyester fabric causes modification to the surface of the hydrophobic fibers from which the fabric is woven, which can improve comfort and other fabric properties [1-5]. It was the most common method of producing silk like polyester until appearance of new generation of polyester fabrics, which contains micro fibers, which have fineness under 1.0 dtex, the bulk and surface area of the normal fibers yarn. Produced textile fabrics are consequently softer and drape better than those made with standard yarn. However, micro fibers contain more oligomers and cause more unlevelness problems. One of the ways to solve this problem is new treatment using ethylenediamine (EDA). Ester-amine interchange reactions have also been researched and surface amine functionality results when diamines are used [6,7]. The use of EDA for short time in ambient conditions results in creation of both amine and carboxylic acid functional groups on the polyester fiber surface, not only carboxylic acid functional groups as in alkaline hydrolysis (Figure 1). The presence of two functional groups provides possibility for better finishing effects.
A good fabric UV protection is a guaranty that clothing will have the ability to protect the skin from incident solar energy. In addition to some beneficial effects of UV radiation (UV-R, 100 nm-400 nm) on skin it may cause skin damage such as sunburn, allergies, skin aging and even skin cancer especially during the summer time. The UV-C radiation (100 nm - 280 nm) get absorbed by

atmosphere, but UV-B (280 nm - 320 nm) and UV-A (320 nm - 400 nm) rays reach the Earth and cause known skin aging and recently the formation of skin malignant neoplasm. Diminishing of the ozone layer raised this risk, what have resulted with large investigation of fabric UV protection [8-10]. It is well known that 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. UV protection highly depends on a large number of factors, such are type of fiber, porosity, density, moisture content, type and conc. of dye, UV-B protective agents, and fluorescence whitening agents (FWA) in the case of white textiles, if applied [9,10]. In new papers of Grancaric et al. UV protection of polyester and cotton fabrics can be accomplish by natural zeolite application [11-13].
Therefore, in this paper surface of polyester fabric for summer clothing purpose was modified by alkaline hydrolysis and aminolysis with EDA (ethylene-diamine) for achieving better UV protection.

2. MATERIAL AND METHODS

Polyester fabric used in the present work was poly (ethylene-terephtalate), PET, previously heat set fabric having surface mass of 100 g/m^2; textured multifilament yarns in both warp and weft directions. Yarn is consisted of delustered fibers with trilobal cross section in warp and circular cross section in weft. It was chemically modified using alkali and ethylene-diamine (EDA). Alkaline hydrolysis (PETH) was performed in 1,5 mol/l NaOH with 2 g/l cationic surfactant Lyogen BPN (Sandoz) as an accelerator by batch wise method in stainless-steel bowls (Linitest, Original-Hanau) for 10 min at 100°C, until the theoretical [5] weight loss of 20 % was accomplished. It was rinsed and neutralized using 1% aqueous hydrochloride acid. Aminolysis using 99 % EDA was performed in closed glass chamber for 3 h at room temperature. Afterwards, samples were rinsed and neutralizing in 1% aqueous hydrochloride acid. Theoretical [6] weigthloss of 4 % was accomplished.

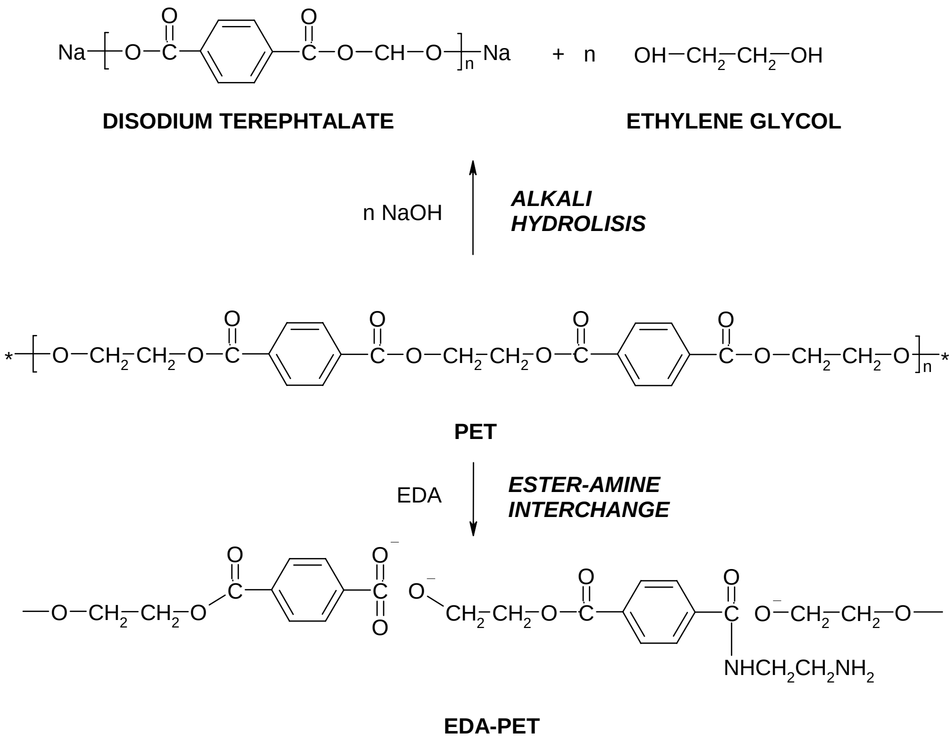

Figure 1. Hydrolysis and aminolysis of polyester

Optical brightening of polyester fabric was performed by thermosol process using fluorescent whitening agent (FWA) Uvitex ERN-P (Ciba), benzoxazole derivate in optimal concentration of 3 g/l. Fabric was dryed at 80°C for 2 min following by setting at 200°C for 30 s. For UV protection, Tinofast PES (Ciba), UV absorber based on triazine derivate, was applied by batch wise method in optimal concentration of 3 % owf in stainless-steel bowls (Linitest, Original-Hanau) for 30 min at 120°C. Durability of these treatments was determined according to ISO 6330:2000 *Textiles* -

Domestic washing and drying procedures for textile testing after 3 washing cycles using standard ECE detergent without FWA's.
Remission spectrophotometer SF 600 PLUS CT (Data-color) was used for measuring CIE whiteness and Yellowing Index according to DIN 6167 *Description of yellowing of practically white or practically colorless materials.* UV-A and UV-B transmissions, τ_{UVA} and τ_{UVB} were measured on transmission spectrophotometer Cary 50 Solarscreen (Varian) according to AS/NZS 4399:1996 *Sun protective clothing - Evaluation and classification*. On the base of these values Ultraviolet protection factor (UPF) was calculated according to:

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

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]

3. RESULTS AND DISSCUSSION

Polyester fabric protective ability from UV radiation (UV-R) was investigated after alkali hydrolysis with NaOH, amimolysis with EDA and treatment with UV absorber and optical brighter. Labels and treatments are in table 1. Results of UV protection measured according to according to AS/NZS 4399:1996, expressed through mean UPF values are shown on Fig. 2.

Table 1. Labels and treatments

Label	Treatment
PET	untreated polyester fabric
PET-H	hydrolyzed polyester fabric with NaOH
PET-EDA	amynolyzed polyester fabric with EDA
…O	optical brightened polyester fabric
… UV	polyester fabric treated with UV absorber

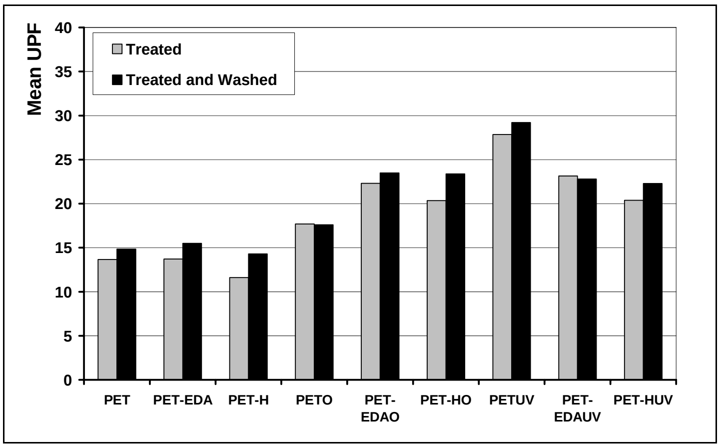

Figure 2. Mean UPF values of polyester fabrics after modifications,FWA and UV absorber treatment; and after washing

UPF indicates how much longer the person can stay in the sun with the fabric covering the skin as compared with the uncovered skin to obtain same erythemal response. Polyester fiber has double bonds in polymer chain which can absorb small amounts of UV-R, therefore untreated fabric give off small UV protection. Nevertheless, small amounts of UV-R are reflected from polyester multifilament. Modification of polyester fabric with EDA results in better UV protection than in alkali hydrolysis. That is because of higher optimal weight loss during alkali hydrolysis. After FWA treatment it is evident that all polyester fabrics give off good UV protection. Polyester fabric modified with EDA, absorb higher amounts of FWA, resulting with the highest UV protection of all polyester fabrics treated with FWA’s. Treatment of polyester results with UV absorber results in very good protection. After the washing process UV protection is higher. Fabrics slightly shrink during the washing, resulting in lower UVR transmission. Standard ECE detergent contains synthetic zeolites, which can additionally scatter the UV radiation.

Spectral characteristics of polyester fabrics were measured using spectrophotometer Datacolor SF 600 PLUS CT. CIE whiteness and yellowness index were calculated automatically. Results are collected in Figure 3. It is evident that optical brightening of polyester fabric results in whiteness great increment. EDA modified fabric absorbs highest amount of FWA, resulting in highest whiteness. Even UV absorber is yellowish, it reacts similar as FWA, increasing CIE whiteness. Washing of modified, FWA and UV absorber treated polyester fabrics results in higher whiteness. Analogue to whiteness increment, yellowing index decreases.

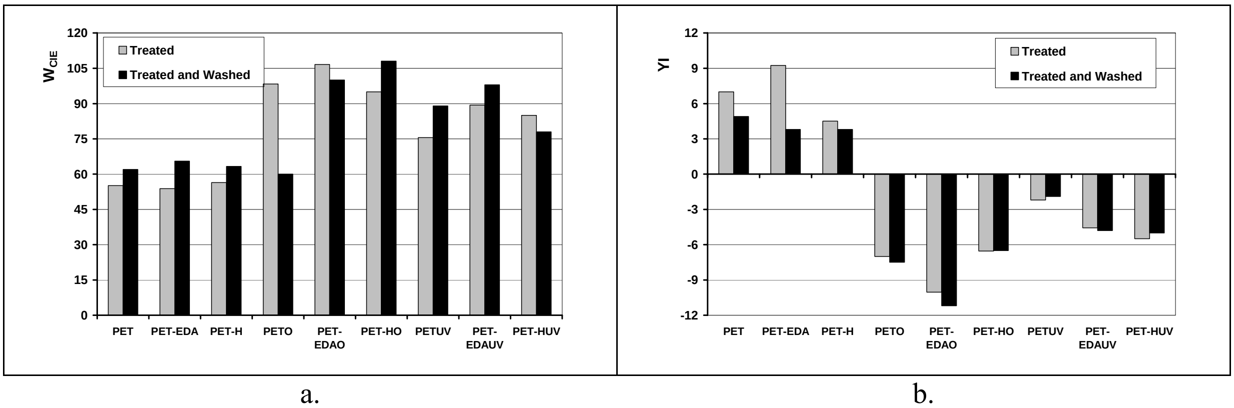

Figure 3. a. CIE whiteness (W_{CIE}) and b. yellowness index (YI) of cotton and polyester fabrics after surface modifications, FWA and UV absorber treatment; and after washing

4. CONCLUSION

Modifications – aminolysis and hydrolysis changes surface of polyester for summer clothing purpose. It slightly increases fabric UV protection, as well.

FWA treatment leads to good UV protection and better whitenss of polyester fabric.

Treatment with UV absorber treatment leeds to very good UV protection and whiteness as well.

As a final conclusion, modified polyester fabrics the same, or even better protective properties, after washing process.

5. REFERENCES

[1] Zeroing H. S., Collins M. J.: Surface modification of Polyester by Alkaline Treatments, Textile Progress, 20 (1989) 2

[2] Pfeifer H.: Uber den Abbau von Polyester fasern durch Hydrolyse und Aminolyse, Westdeutscher Verlag, Köln, (1964), Germany

[3] Gorraffa, A. M.: Caustic Treatment of Polyester Filament Fabrics, AATCC Review 12 (1980) 4, 83-87

[4] Kallay N., Grancarić, A. M., Tomić, M: Kinetics of Polyester Fibre Dissolution, *Text. Res. J.* 60 (1990) 663-669

[5] Grancarić A. M., Kallay N.: Influence of Electrokinetic Potential upon Adsorption of Cationic Surfactants, J. Appl. Polym. Sci. 49 (1993) 175-181

[6] Bide, M. et al.: Bifunctional Surface Modification of Polyester, AATCC Review 3 (2003) 11, 24-28

[7] Avny, Y., Rebenfeld, L.: Chemical modification of polyester fiber surfaces by amination reactions with multifunctional amines, J. Appl. Polym. Sci, 32, (1986) 3, 4009 – 4025

[8] Reinert G. et al.: UV Protecting Properties of Textile Fabrics and their Improvement, Textile Chemists and Colorists, 29 (1997) 12, 36-43

[9] Grancarić, A.M. et al. UV Protection of Pretreated Cotton - Influence of FWA´s Fluorescence, AATCC Review, 6 (2006) 4; 40-46

[10] Algaba I., Riva A., Crews P. C.: Influence of Fiber Type and Fabric Porosity on the UPF of Summer Fabrics, AATCC Review, 4 (2004) 2, 26–31

[11] Tarbuk, A. et al.: UV Protection with surface modified polyester fabric (in Croatian), Tekstil 55 (2006) 8, 383-394

[12] Grancarić, A. M. Tarbuk, A. McCall, D. Surface Modification of Polyester Fabric with Tribomechanical-activated Natural Zeolite (TMAZ) Nanoparticles; Polimeri, 28 (2007) 4, 219-224

[13] Grancarić, A. M. Marković, L. Tarbuk, A.: Active multifunctional cotton treated with zeolite nanoparticles, *Tekstil* 56 (2007) 9, 543-553