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UV Protection Finishing of Natural and Blend Textiles Using *Succinite* Microparticles

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Abstract: In order to prevent or reduce the effects of UV on the human body, there are several ways to protect skin from UV exposure, such as cosmetics, lotions and clothing, but each of them have their own pros and cons, such as the formation of cosmetic allergies, dislike of aromas, and lack of air proof and dislike of textile composition and temperature proof. So much emphasis is placed on natural products and materials, which for humans has minimal risk, good optical properties of UV radiation weakening and air permeability. It is known that *Succinite* possesses excellent optical properties and non-allergenic properties. The aim of this work is to compare optical absorbency of materials with different combinations of natural fibers and fibers with *Succinite* microparticles, and their ability to reduce the exposure in UV range 280-400 nm. To compare optical absorbency in UVB (280–315 nm) and UVA (315 400 nm), as well calculate of the ultraviolet protection factor UPF both before and after laundering of the treaded samples. Application of *Succinite* microparticles treatment of cotton and polyamide/cotton blend fabrics UV protection is studied. The effectiveness of the treatment is assessed using the standardized tests, such as UV-V is spectrophotometry (using spectrophotometer UV – Vis Thermo Spectronic Heλios) and the calculation of the ultraviolet protection factor UPF both before and after rinsing of the trodden samples. UPF were calculated according to AATCC Test Method 183. It is found that the performance of *Succinite* particles as UV-absorbers can be efficiently transferred to fabric materials through the impregnation. The UV tests indicate a significant improvement of UV absorbing activity of *Succinite* treated textiles.

Keywords: Succinite, Polyamide/Cotton Blends, Cotton Fabrics, Ultraviolet Protection Factor

1. Introduction

The application of *Succinite* microparticles (Baltic amber) in the structure of finishing textile materials can protect from UV radiation because they contain optically active substances like Monoterpenes, class of terpenes, like camphor (Camphor $C_{10}H_{16}O$) is optically active substance, which has two optical isomers and racemic mixture with lower melting temperature [1]. Camphor molecules contain two asymmetric carbon atoms, despite the fact that out of four mirroring isomers only two mirroring isomers are known, because unknown isomers are too unstable, which is caused by overtight chemical bonds. The most common is d-camphor, the optical polarization plane of which is shifted to the right. Usually, “camphor” is meant exactly by this isomer. Borneols $C_{10}H_{18}O$ is terpene, which consists of planes and protect them from UV radiation (the study of impact of UV-B radiation on indoor grown spruce seedling, as a result of epigenetic reaction observation i.e. terpene emission, which concluded that the plants will increase terpene substance in order to protect them from UV-B radiation) [2]. Nowadays, the human skin is exposed to ultraviolet (hereinafter UV) radiation, which is one of the factors causing skin damage (including melanoma). Everyone is exposed to UV exposure by sun and artificial sources used in various industries. UV radiation is divided into three modules: UVA (315-400 nm), UVB (280-315 nm), UVC (100-280 nm), only first two radiation types reach earth surface, where UVA exposure on the human body synthesizes vitamin D, UVB exposure on the human skin causes mutation of DNA and inhibit the immune system. UVC exposure in the human body causes burns and development of skin damage known as melanoma, but UVC radiation is held by ozone layer [3]. It is also known that the degradation of ozone layer increases the amount of UV radiation to the earth surface and shorter wavelength UV rays can reach the surface, which are particularly dangerous to human health [4-6].

In order to prevent or reduce the effects of UV on the human body, there are several ways to protect skin from UV exposure, such as cosmetics, lotions and clothing, but each of them have their own pros and cons, such as the formation of cosmetic allergies, dislike of aromas, and lack of air proof [7] and dislike of textile composition and temperature proof. So much emphasis is placed on natural products and materials, which for humans has minimal risk, good optical properties of UV radiation weakening and air permeability [8].

It is known that *Succinite* possesses excellent optical properties and non-allergenic properties [9]. Modern technology has taken a big step in *Succinite* fiber production [10].

The aim of this work is to compare optical absorbency of materials with different combinations of natural fibers and fibers with *Succinite* microparticles, and their ability to reduce the exposure in UV range 280-400 nm. To compare optical absorbency in UVB (280–315 nm) and UVA (315 400 nm), as well calculate of the ultraviolet protection factor UPF both before and after laundering of the treaded samples.

2. Materials and Methods

Textile knitting materials were prepared using machine BUSI 334 IDEA TERRY (IT). The size of each material samples (in the form of a tube) was: diameter 10 cm, sample length 30 cm, with the same depth of knitting (b density, it corresponds a position of knitting mechanisms, which is not changed in the process of knitting of all samples), single interlacing. After 24 hours of relaxation of textile knitted materials, they were thermally fixed in standard thermal fixation machine S2000N® ERMEST (FR) for 2,0 minutes. After thermal fixation textile knitted materials were relaxed under normal conditions for 24 hours. To research UV protection factor, samples (size 1 cm x 3 cm) were cut out from the textile knitted materials (to obtain reliable results, 5 samples from each type of textile knitted materials were prepared), which were placed in a chamber spectrophotometer UV – Vis Thermo Spectronic Heλios, which has the following preset parameters: Measuring range selected from 190 nm to 400 nm; Data interval 0-3 A (UV Absorbency); Type of test – absorption measurements. Scanning speed – according to device default setup.

UPF were calculated according to AATCC Test Method 183: Transmittance or Blocking of Erythemally Weighted Ultraviolet Radiation through Fabrics (AATCC, 2002) [11].

Cotton samples (in the form of a tube) were impregnated with amber suspension in time of 5 min. (Table 2), then they were dried in the expanded state in the Petri Dish for 24 hours (held in normal conditions). Characteristics for preparation of amber suspension: 1% suspension included - Amber powder (1.00 g), Aqua (distilled water) (96.84 g), Macadamia Trenifolia Seed Oil (2.00 g), Polysorbate 80 (0.10 g), Hydroxypropyl (0.06 g); 10% suspension included - Amber powder (10.00 g), Aqua (distilled water) (79.44 g), Macadamia Trenifolia Seed Oil (10.00 g), Polysorbate 80 (0.50 g), Hydroxypropyl (0.06 g).

All samples (described in Tables 1-3) were rinsed in distilled water (20°C) for 5 min and were dried in the expanded state in Petri Dish under normal conditions for 24 hours.

The optical absorbency in UVB (280–315 nm) and UVA (315–400 nm) ranges, and the calculation of the ultraviolet protection factor UPF were determined both before and after rinsing of the treaded samples.

3. Results and Discussion

Figure 1 shows compare UV absorbance of the knitting samples made from PA6 (textured) 7.8 Tex & PA6 (complex fibers) 7.8 Tex and PA6 (textured) 7.8 Tex & PA6 (complex fibers) with amber coating 7.8 Tex.

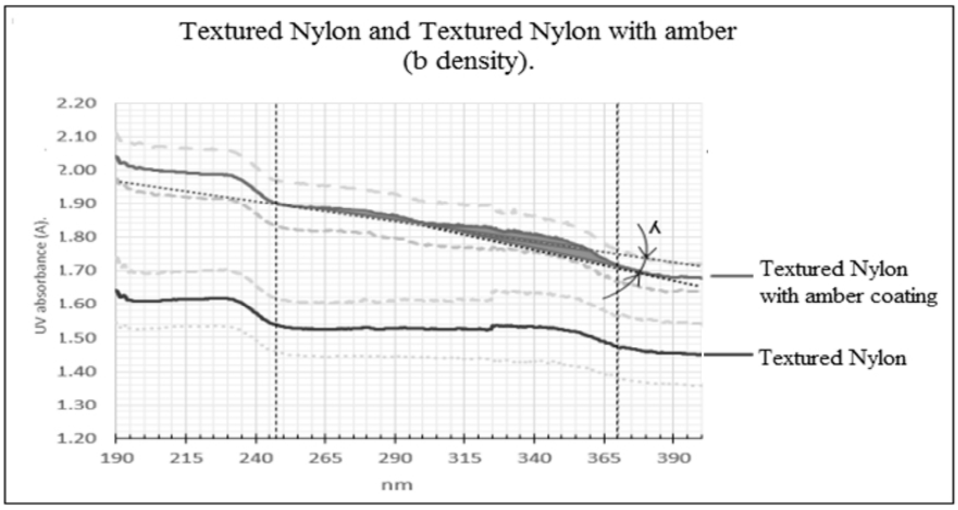

Figure 1. *Compare UV absorbency of the knitting samples made from PA6 (textured) 7.8 Tex & PA6 (complex fibers) 7.8 Tex and PA6 (textured) 7.8 Tex & PA6 (complex fibers) with amber coating 7.8 Tex.*

UV absorbency average value over the whole measurement range of textured nylon and complex nylon with the amber coating is 1.85. While textile material, which is only knitted from a textured nylon and complex nylon is 1.52. UV absorption through its range is increased by 0.31A. Using Beer–Lambert law was calculated how this material decreased UV radiation, in these case 0.31A = 2.04 times, it means that the samples made from PA6 (textured) 7.8 Tex & PA6 (complex fibers) with amber coating 7.8 Tex in 2.04 times more protected from UV radiation.

It is concluded that the textile material knitted from the textured nylon and complex nylon with amber coating protects λ time better from UV radiation as UV absorption thought its range has increased by 0.32 A (2.09 times), where in UVB range of 0.32 A (2.14 times) and in UVA range of 0.26 A (1.82 times), (see Table 1).

Table 1. *Summary of UV absorbency in UVA and UVB ranges.*

Textile samples	UV absorbency (A) in UVB range (280- 315 nm)	UV absorbency (A) in UVA range (315-400 nm)
Samples from PA6 (textured) 7.8 Tex & PA6 (complex fibers) 7.8 Tex (white color)	1.5	1.52
Samples from PA6 (textured) 7.8 Tex & PA6 (complex fibers) with amber coating 7.8 Tex (yellow color)	1.82	1.78

PA6 (complex fibres) with amber coating 7.8 Tex it means - polyamide matrix (PA6) (organic high molecular compounds, composed of repetitive linear polymer structural units of polyamide) with integrated amber particles sizes from 800 nanometers up to 3 micrometres [1]. The concentration of amber particles is up to 3%. The amber particles are located only on the surface of the polymer filaments (one fibre comprises 12 filaments) and tightly bound to the polymer. Amber particles are coated with an average of 20% of the surface of the polymer fibre. The concentration of amber particles - up to 3% it is necessary and sufficient to ensure a positive bioactive influence on the cells structure, as well as providing protection of the human body from UV radiation. The composite amber fibers are not toxic and not allergic (Certificate Oeko-Tex® Standard 100 AITEX Nr. 2913LK0012 23.09.2013 (extended till now); Certificate Oeko-Tex® Standard 100 AITEX MADE for HEALTH Nr. 2014TM0281 27.05.2014. Composite Amber threads the products of personal hygiene and medical devices (extended till now)).

Figure 2 shows compare UV absorbance of the knitting samples made from cotton yarns (non mercerized) Nr 100/2x2 (impregnated 1% and 10% of amber suspension) and cotton yarns (non mercerized) Nr 100/2x2. Comparing the UV absorption spectrum of cotton samples and cotton samples impregnated with 1% and 10% amber suspension, it appears that UV absorption spectrum for the cotton samples is practically a straight line, but for cotton, samples were impregnated with 1% and 10% amber suspension, it is a spline. UV absorbency average value over the whole measurement range of the impregnated cotton samples (impregnated of 1% amber suspension) increase 0.48 A (2.95 times more). UV absorbency average value over the whole measurement range for the impregnated cotton samples (of 10% amber suspension) increase 1.33 A (21.38 times more).

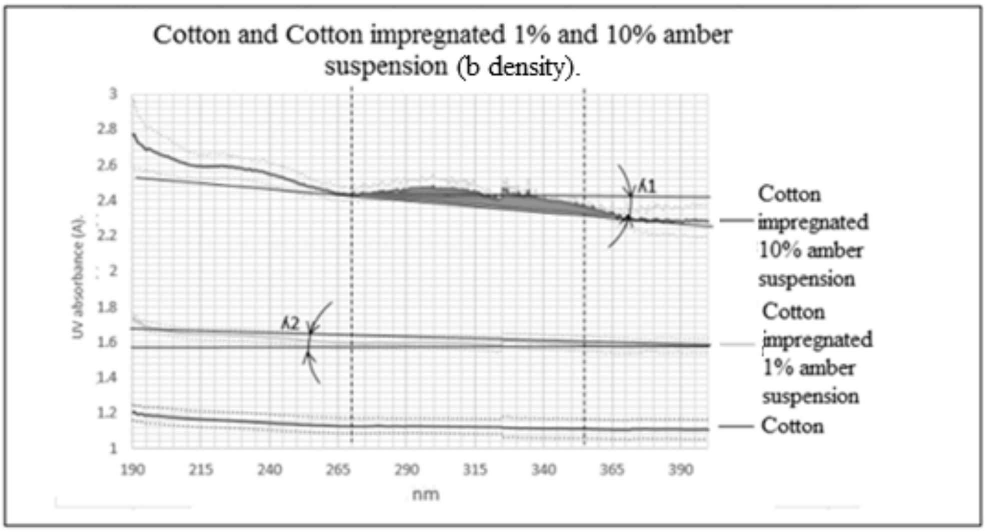

Figure 2. *Compare UV absorbency of the knitting samples made from cotton yarns (non mercerized) Nr 100/2x2 (impregnated 1% and 10% of amber suspension) and cotton yarns (non mercerized) Nr 100/2x2.*

The absorbency spectra of the textile materials knitted from the cotton fibers impregnated with 1% and 10% amber suspension are better protected from UV radiation in λ1 and λ2 times than textile materials knitted from the cotton fibers without impregnation of amber suspension, (see Table 2).

Table 2. *Summary of UV absorbency in UVA and UVB ranges.*

Textile samples	UV absorbency (A) in UVB range (280-315 nm)	UV absorbency (A) in UVA range (315-400nm)
Cotton samples from cotton yarns (non mercerized) Nr 100/2x2, impregnated of 1% amber suspension	1.6	1.59
Cotton samples from cotton yarns (non mercerized) Nr 100/2x2, impregnated of 10% amber suspension	2.46	2.35
Cotton samples from cotton yarns (non mercerized) Nr 100/2x2	1.45	1.45

Figure 3 shows compare UV absorbance of the knitting samples made from cotton yarns (non mercerized) Nr 100/2x2; cotton yarns (non mercerized) Nr 100/2x2 & PA6 (textured) 7.8 Tex & PA6 (complex fibres) with amber coating 7.8 Tex; cotton yarns (non mercerized) Nr 100/2x2 & PA6 (complex fibres) with amber coating 7.8 Tex x 2.

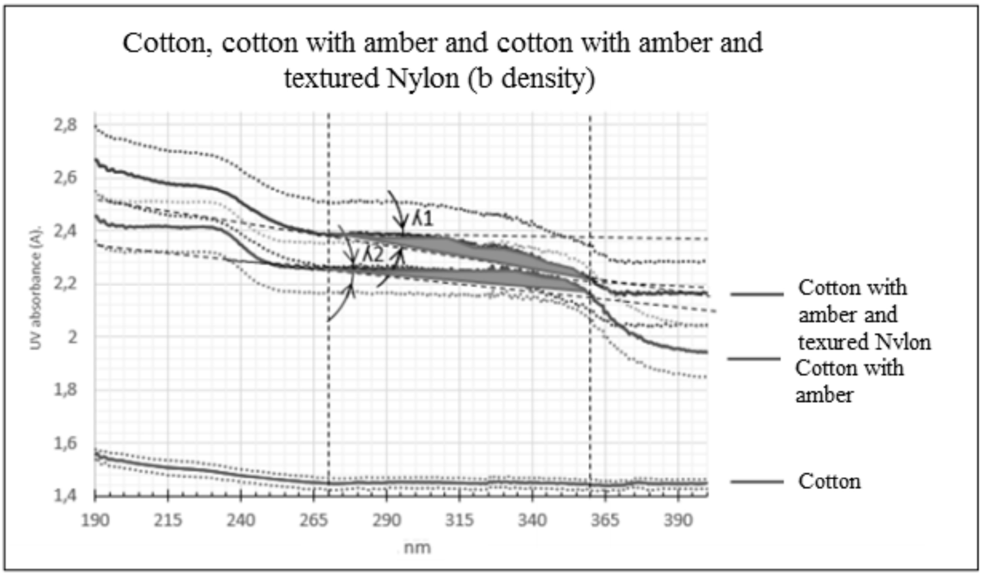

Figure 3. *Compare UV absorbency of the knitting samples made from cotton yarns (non mercerized) Nr 100/2x2; cotton yarns (non mercerized) Nr 100/2x2 & PA6 (textured) 7.8 Tex & PA6 (complex fibres) with amber coating 7.8 Tex; cotton yarns (non mercerized) Nr 100/2x2 & PA6 (complex fibres) with amber coating 7.8 Tex x 2.*

Absorbency average value over the whole UV measurement ranges of the cotton samples with amber cover and cotton samples with textured nylon & amber cover increased in λ1 and λ2 times more compared with textile materials knitted only from cotton yarns: 0.39 A (2.45 times more) and 0.53 A (3.39 times more), (see Table 3).

Table 3. *Summary of UV absorbency in UVA and UVB ranges.*

Textile samples	UV absorbency (A) in UVB range (280-315 nm)	UV absorbency (A) in UVA range (315-400 nm)
Cotton samples from cotton yarns (non mercerized) Nr 100/2x2 & PA6 (textured) 7.8 Tex & PA6 (complex fibers) with amber coating 7.8 Tex	2.38	2.24
Cotton samples from cotton yarns (non mercerized) Nr 100/2x2 & PA6 (complex fibers) with amber coating 7.8 Tex x 2	2.26	2.13
Cotton samples from cotton yarns (non mercerized) Nr 100/2x2	1.45	1.45

Under all equal experimental conditions, the samples with textured polyamide in their structure show better protection from UV radiation.

Why is this happening? Textured PA6 yarns are high volume yarns. The loopy structure is in the stress-strain state after the knitting process after relaxes and strive to occupy the greatest volume. Thus, loopy structure remains practically without gaps. Therefore, the beam falling on the surface of the loopy structure is repeatedly reflected from the textured filament yarns (including partially absorbed) and a negligible percentage of UV radiation passes through the material.

Therefore, in order to compare samples of one group (Tables 1-3) (developed under the same knitting conditions and the same content (percentage) of yarns) a surface loop module used. Which characterizes the translucence through the loop [12].

Values of surfaces loop modules all samples is shown in Table 4. For example, for a group of samples from Table 1 (developed under the same knitting conditions and the same content (percentage) of yarns) the surfaces loop modules are different. In this case, on loopy translucency has effect of yarn structure, namely textured yarn or not. With all equal conditions, the lower value of surface loop module, the greater protection from ultraviolet radiation, while textured yarn has a decisive importance for protection against ultraviolet radiation (as follows from comparison of values the surfaces loop modules, Table 4).

Table 4. *Effect ultraviolet protection factor (UPF) values of knitting samples.*

Textile samples	Surfaces loop modules	Stand. error	UVB %	UVA %	UPF before rinsed	UPF after rinsed	Protec. category
Samples from PA6 (textured) 7.8 Tex & PA6 (complex fibers) 7.8 Tex (white color)	5.7	0.1	1.5	1.52	4	4	none
Samples from PA6 (textured) 7.8 Tex & PA6 (complex fibers) with amber coating 7.8 Tex (yellow color)	4.6	0.4	1.82	1.78	5	5	none
Cotton samples from cotton yarns (non mercerized) Nr 100/2x2, impregnated of 1% amber suspension (yellow color)	1.92	0.2	1.6	1.59	8	8	none
Cotton samples from cotton yarns (non mercerized) Nr 100/2x2, impregnated of 10% amber suspension (yellow color)	1.71	0.7	2.46	2.35	18	15	good
Cotton samples from cotton yarns (non mercerized) Nr 100/2x2 (white color)	1.93	0.1	1.45	1.45	3	3	none
Cotton samples from cotton yarns (non mercerized) Nr 100/2x2 & Pa6 (textured) 7.8 Tex & PA6 (complex fibers) with amber coating 7.8 Tex (light yellow color)	1.55	0.3	2.38	2.24	22	22	good
Cotton samples from cotton yarns (non mercerized) Nr 100/2x2 & Pa6 (complex fibers) with amber coating 7.8 Tex x 2 (light yellow color)	1.65	0.2	2.26	2.13	20	20	good
Cotton samples from cotton yarns (non mercerized) Nr 100/2x2 (white color)	1.93	0.1	1.45	1.45	3	3	none

Results of the effect both before and after rinsing on ultraviolet protection factor (UPF) values of knitting samples for blended cotton samples (including samples impregnated of amber suspension) are shown in Table 4. Conventional, bleached cotton exhibited UPF values <4, which means that it offers little sun protection. A UPF rating of 15 or above is required before a fabric may be labelled sun protective according to the voluntary ASTM D6603 Standard Guide for Labeling of UV-Protective Textiles (ASTM, 2004). Analysis of UPF values of the conventional blended cotton shows that laundering not significantly affected its mean UPF value.

Protection category start from 15 (good) (only for Nm of fabrics 4, 6, 7): these fabrics are effective as protection against solar ultraviolet radiation (UVR) (both before and after laundering of samples) as they have an ultraviolet protection factor (UPF) greater than 15. A material with a rating of UPF 15 reduces the amount of solar UVR by a factor of 15.

The fabrics (Nm 1, 2, 3, 5, 8) are not effective as protection against solar ultraviolet radiation (UVR) as they have an ultraviolet protection factors UPF (1 and 5) less than 15. These fabrics failed to quality for any of the UPF rating categories.

4. Conclusion

Performance of *Succinite* microparticles as an UV absorber on the surface of cotton fibers and nylon fibers can be successfully used. UV radiation absorbency throughout all UV range increased to the materials in which *Succinite* microparticles were used. That means that *Succinite* can absorb and reflect UV radiation. The UV tests indicate a significant improvement of UV absorbing activity of *Succinite* treated textiles. Such results can be exploited for the protection of the body against ultraviolet radiation.

In UV radiation absorbance spectrum, to the textile materials that are knitted from textured nylon with amber yarn is changed it spectrum angle and in 247-370 nm range appears curves.

With all equal conditions, the lower value of surface loop module, the greater protection from ultraviolet radiation, while textured yarn has a decisive importance for protection against ultraviolet radiation textured yarn has a decisive importance for protection against ultraviolet radiation.

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