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Investigations on the effects of UV Finishes using Titanium Dioxide on Silk and Lyocell Union Fabrics

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ABSTRACT

The increased incidence of skin cancer in recent years has resulted in investigations on the effects of UV radiation. An attempt has been made to produce UV-resist fabrics using Titanium dioxide in lyocell and silk union fabrics. The treated and untreated samples are characterized using SEM/EDS and FTIR. The effectiveness of the treatment is assessed using the standardized tests, such as UV-Vis spectrophotometry and the calculation of the ultraviolet protection factor both before and after washing of the treated samples. It is found that TiO2 as a UV finish can be efficiently given to silk and lyocell union fabrics. The UV tests indicate a significant improvement in the UV absorbing activity in the TiO2 treated fabrics. Samples treated with UV finish showed good fastness properties up to 25 washes. The effect of UV finish on air permeability, absorbency, wickability, tensile strength, crease recovery and drapability was also observed. UV finished fabrics show a marginal decrease in tensile strength, absorbency, crease recovery and air permeability.

Keywords: UV-resistant fabrics, treated fabrics, ultraviolet protection

1. Introduction

The survival of textile industry depends primarily on the diversification of end products to meet the national as well as international demands.[1] Textile materials containing more than one kind of fiber are termed as blend, union or mixture. The reasons for developing such fabric unions may be to economize on raw material cost (if one of the component fibers is relatively expensive), to modify / confer aesthetic properties or to develop a material with specific physical characteristics.[2,3] The characteristic properties of lyocell are soft handle, luster and moisture absorbency that makes it suitable for a blend or a union fabric.[4] Lyocell is defined as a cellulosic fiber that is produced by regenerating cellulose into fiber form out of solution in an organic solvent.[5] It is 100% natural in origin as it is made from wood pulp and is fully biodegradable.[6] Silk is a protein fiber, which consists of two single endless filaments surrounded by silk gum (or sericin).[7,8]

Owing to its inherent natural softness and luster, silk too is an ideal material for garments. However, silk is not easily affordable to most of the people in India, due to its high cost. Lyocell has similar appearance, moisture content, strength and luster like that of silk. The cost of lyocell is less than $1/3^{rd}$ of silk. The appearance and properties of both silk and lyocell are similar to each other to the maximum extent. Thus, considering the properties of silk and the cost of lyocell, an attempt is made in the present study to mix silk and lyocell yarns so that even a common person can enjoy the unique richness of silk with excellent softness of lyocell. This study is an effort to merge the richness of silk with the brilliancy of lyocell that offers cost effective and yet attractive fabric that can be used as apparels for men, women and children.[1]

Recent market survey shows that the apparel consumers all over the world are demanding functionality in the product. Some of the best examples of functionality are product attributes such as wrinkle resistance, soil release, water repellency, flame retardancy, fade resistance and resistance to microbial invasion.[9] People have been using textile materials and clothing since the ancient times for the protection, comfort and adornment. More recently, advanced material technology makes it possible to turn clothing into a guard against skin cancer particular melanoma caused by excessive exposure to ultraviolet radiation (UVR) from the sun.[10] Recently, consumers have become increasingly aware of the need for sun protection, which is related to the incidence of sun-induced skin damage and its relationship with an increased exposure to UV light. Besides avoiding the sun, the most frequently recommended form of UV protection is the use of suitable clothes, hats, and sunscreens.[11]

UV-resist property can be given by changing the structure of the constituent fibers, varying the weave, changing the shades in dyeing, or applying a suitable finishing agent on the fabric.[9] UV protection fabrics has recently become the focus of great interest, particularly in connection with environmental degradation or ozone layer depletion. Clothing is perceived as a good means of sun protection.[12] Now, there is a growing demand for casual and active apparel giving added value to the wearers without hindering the level of comfort. Fabrics with greater levels of sun protection can have a competitive edge in an increasingly health-conscious age.[10]

B. R. Das et.al., provided insight on how UV absorbers can be efficiently used with textile material to protect human skin from harmful UV radiation. The manufacturers of various UV absorbers and their commercial products were reviewed and discussed. The interacting mechanism of UV absorbers with textile clothing for providing UV protection and an evaluation of the performance of UV absorbers were summarized.[13] H. M. Fahmy et.al., studied UV protection by treating with copper acetate and zinc acetate and found that copper acetate has a higher extent of UV protection than zinc acetate.[14] P. De et.al., produced a UV-resist, breathable fabrics for use in the cold regions of India. For UV-resist property, a dispersion of benzotrizol-type derivative and a silicone-based product were taken and perfluoroalkyl- type fluorocarbon-based compound and fluorocarbon resin-type compound were used as water-repellent finishes. Both chemicals showed good wash fastness.[9]

Lavanya Krishnan et.al., summarizes the known facts about skin cancer and the understanding achieved until now to utilize clothing as a means of preventing skin cancer. It highlights the advances in the areas of clothing design and use and also the advances made in terms of measuring and characterizing the UV protective performance of clothing materials.[15] Roshan Paul et.al., developed a Ultraviolet resistant cotton fabrics by coating with ZnO and TiO2 nanoparticles. Knitted fabrics containing ZnO nanoparticles showed moderate to high ultraviolet protection factor (UPF) values, whereas 50+ UPF values were measured for the TiO2-coated samples. The developed process can be easily adapted to the existing textile machinery, making it industrially viable.[16]

The present work addresses the application of TiO_2 on silk and lyocell union fabrics to develop UV-resist fabric suitable for garments and thereby protecting it from UV radiation.

2.0 Materials and Methods

2.1 Materials

Five types of fabric samples were used. These fabrics were made from pure lyocell of 30s count (bleached and reactive dyed) and pure silk of 70s denier with 2 ply filament (degummed and reactive dyed) by plain weave. The fabric construction details are given in Table – 1.

Table 1 – Details of the fabric used for the study

Samples	Warp	Weft	GSM	Ends/inch	Picks/inch
Sample 1	Lyocell	Lyocell	113	160	100
Sample 2	Silk	80% Lyocell 20% Silk	85.5	160	100
Sample 3	Silk	60% Lyocell 40% Silk	67.18	160	100
Sample 4	Silk	50% Lyocell 50% Silk	67.08	160	100
Sample 5	Silk	Silk	51.8	160	100

ISYS SUN purchased from CIBA Chemicals was used for the treatment of UV finish. The chemicals mentioned elsewhere in this study are of AR grade.

2.2.0 Methods

2.2.1 Application and Testing of UV finish on fabrics

To acquire UV protection property on the fabric samples ISYS SUN (6% owf) was applied to the pretreated[12] material with MLR 1:10 and pH around 5.5. The finishing bath was set at 50^0 C, and the samples were treated in the solution for half an hour and passed in a padding mangle, dried at 80^oC and cured at 130^oC for 3 minutes.

The standard method used for determining the UPF was AATCC 183 – 1999 (Transmittance or Blocking of Erythemally weighted Ultraviolet Radiation through fabrics) using Shimadzu UV/Vis Spectrophotometer. UV transmittance through the fabric samples was determined within a wave length range from of 280 to 400 nm using a Shimadzu UV/V is Spectrophotometer. The ultraviolet protection factor (UPF) was computed as the ratio of the erythemally weighted ultraviolet radiation (UV-R) irradiance at the detector with no specimen to the erythemally weighted UV-R irradiance at the detector with specimen present. The percent blocking of UVA and UVB radiation was also calculated.

2.2.2 Characterization of fabrics

2.2.2.1 FTIR

The infrared absorption spectra of the various samples were recorded in the range of 400- 4000 cm-1 using a SHIMADZU FTIR spectrophotometer, at a resolution of 2 cm-1with background correction for 350 scans in the ATR mode.

2.2.2.2 SEM analysis and EDX

A scanning electron microscope (SEM), model JEOL SEM JSM -6360 was used to observe both the morphology and composition of the TiO_2 coated fabric sample. Energy dispersive X-ray (EDX) microanalysis measurements were carried out using a system fitted on the SEM, coupled to an energy-dispersive X-ray spectroscopy (EDX) detector for the acquisition of X-ray spectra. This will allow the identification of the elements present in the surface of the sample.

2.2.3 Air Permeability

Air permeability of the fabrics was obtained by KES-F8-AP-1 air permeability tester in $cm^3/cm^2/sec$.

2.2.4 Absorbency

Absorbency of treated and untreated fabric was evaluated by water drop method as per AATCC 79-2000.

2.2.5 Wickability

The strip test[15] was employed to measure the capillary action of fabrics. A sample (20 cm X 2.5 cm) was suspended vertically with its lower end immersed in a reservoir of distilled water for 10 min, and the height attained by the water in the fabric above water level in the reservoir was noted in centimeter.

2.2.6 Tensile strength

Tensile strength, one of the important physical parameters, of the treated and untreated (control) fabrics, was evaluated using the Instron tensile tester following the ASTM D 5035-2006 method.

2.2.7 Crease recovery angle

Crease recovery angles of treated and control fabrics were measured on a Shirley crease recovery tester as per standard method, IS:4681(1968).

2.2.8 Drapability

Drape coefficient of the silk and lyocell/silk union fabric was measured using Drapemeter.

2.2.9 Wash durability of UV treated fabrics

Fastness to washing for the finished samples was carried out by following the method ISO: 6330-1984 E[21] to determine the durability of the finishes to washing after being subjected to 25 wash cycles.

3.0 Results and Discussion

3.1 UV Protection analysis on treated fabrics

The UPF values and the percent blocking of UV radiation for UV-A and UV-B for the treated sample and treated sample after 25 washes are given in Table 2a and 2b respectively. The data reflect higher protection against UV radiation for all the samples, particularly for Sample 1, 2 and 3. The treated fabrics were tested after 25 washes again and the UV finish was found to be durable up to 25 washes. This clearly indicates that finish was well bound to the fabric.

Table 2a – Assessment of UV Protection Factor for the treated samples

Samples	Mean UPF	Mean UV-A Transmission	Mean UV-B Transmission	Standard Deviation	Calculated UPF Rating	UVA Blocking %	UVB Blocking %
Sample 1	99.113	1.722	0.929	9.320	50+	98.278	99.071
Sample 2	67.039	2.263	1.497	2.372	50+	97.737	98.503
Sample 3	58.118	2.941	1.987	2.221	45	97.059	98.013
Sample 4	36.550	3.113	2.865	4.643	30	96.887	97.135
Sample 5	22.951	4.977	4.573	1.587	20	95.023	95.427

Table 2b – Assessment of UV Protection factor for treated samples after 25 washes

Samples	Mean UPF	Mean UV-A Transmission	Mean UV-B Transmission	Standard Deviation	Calculated UPF	UVA Blocking %	UVB Blocking %
Sample 1	22.741	4.798	4.621	1.562	20	95.202	95.379
Sample 2	15.879	5.714	5.965	0.165	15	94.286	94.035
Sample 3	14.687	8.265	6.620	0.483	14.12	91.735	93.38
Sample 4	14.687	8.231	6.520	0.312	14	91.769	93.48
Sample 5	13.793	8.397	7.116	0.677	13.2	91.603	92.884

UPF Ratings and Protection Categories

UPF Rating	Protection Category	% UV radiation Blocked
UPF 15 - 24	Good	93.3 - 95.9
UPF 25 - 39	Very Good	96.0 - 97.4
UPF 40 - 49	Excellent	97.5 or more
UPF50+	Considered the Ultimate in UV Sun Protection	

3.2 FTIR study on untreated and treated fabrics

Figures 1 show the Fourier transform infrared (FTIR) spectra of both the untreated and treated Sample 2. It is clear that both spectra have similar peaks such as peak at 3285 cm^{-1}, which is corresponding to the –OH stretching band of cellulose, peak at 2925 cm^{-1}, which is corresponding to the C-H stretching. Moreover, the spectrum of treated sample includes a wide peak at 1727 cm^{-1} corresponding to C=O group of carboxylic acid and a peak at 1260 cm^{-1}, which is assigned to the C-O of ester groups.

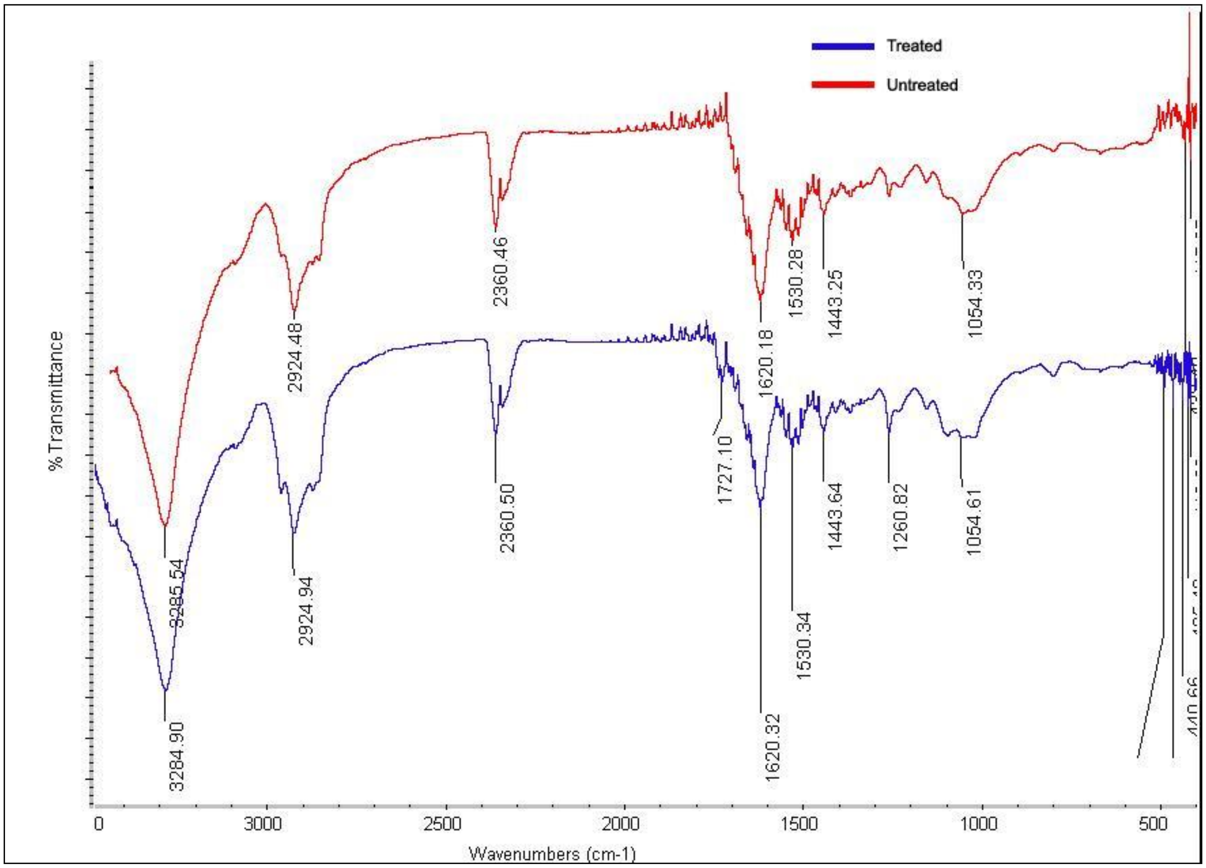

Figure 1 - FTIR spectrum obtained from untreated and treated sample 2

3.3 SEM and EDX analysis on untreated and treated fabrics

The details of SEM and EDX analysis of representative samples (untreated sample and treated sample 2) are given in Figure 2 and 3 respectively. From figure 3, it is seen that the presence of titanium dioxide appears homogeneously on the fabric surface. Subsequently, a suitable way to gain information of TiO_2 being present on the fabric comes from SEM – EDX analysis.

An elemental analysis of the particles was implemented by a SEM equipped with an energy disperse X-ray spectrum (EDX), which provides a rapid qualitative and quantitative analysis of the elemental composition. Figure 4 shows the EDX quantitative analysis for lyocell and silk union fabric treated with titanium dioxide and it confirms the presence of titanium dioxide.

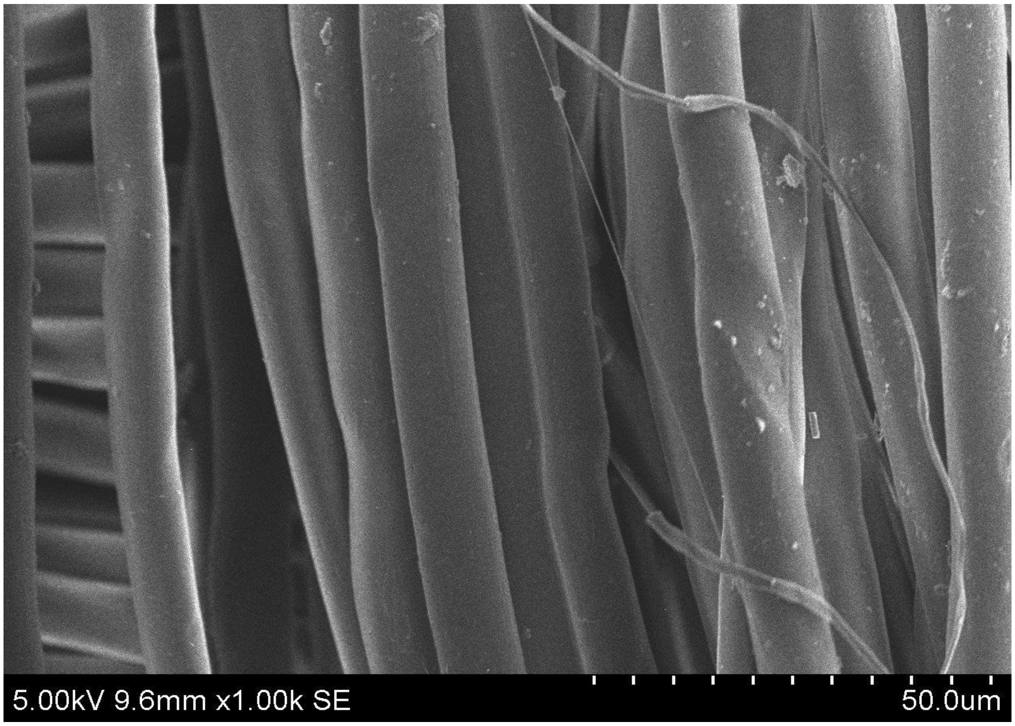

Figure 2 - SEM image for untreated sample 2

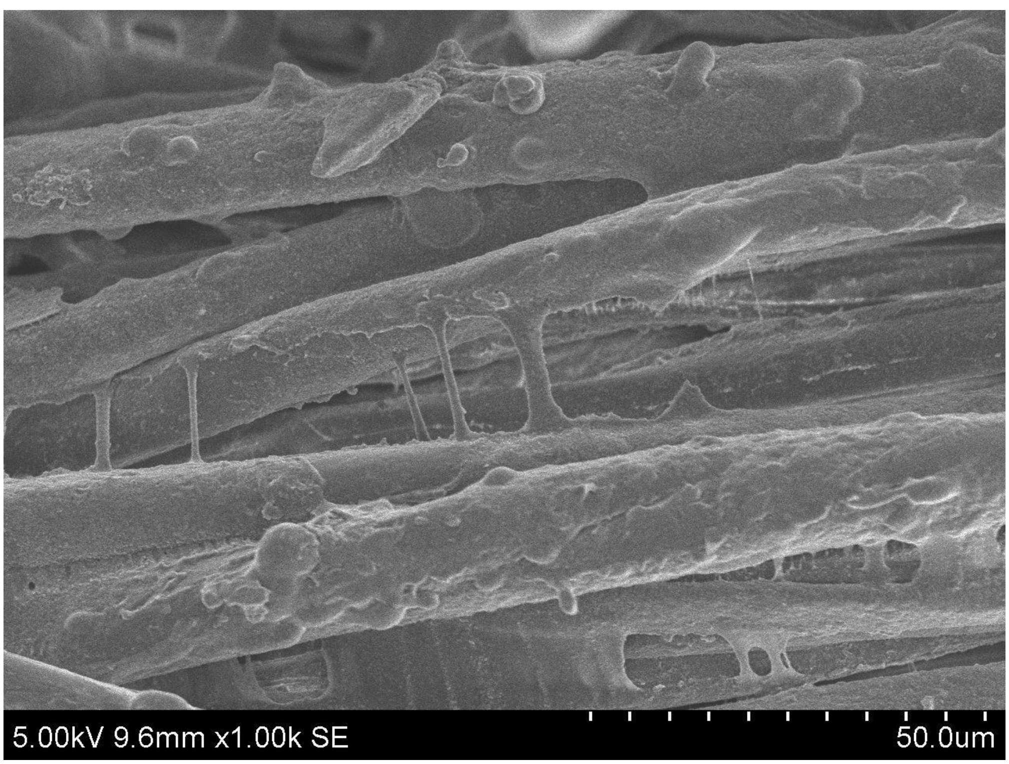

Figure 3 - SEM image for treated sample 2

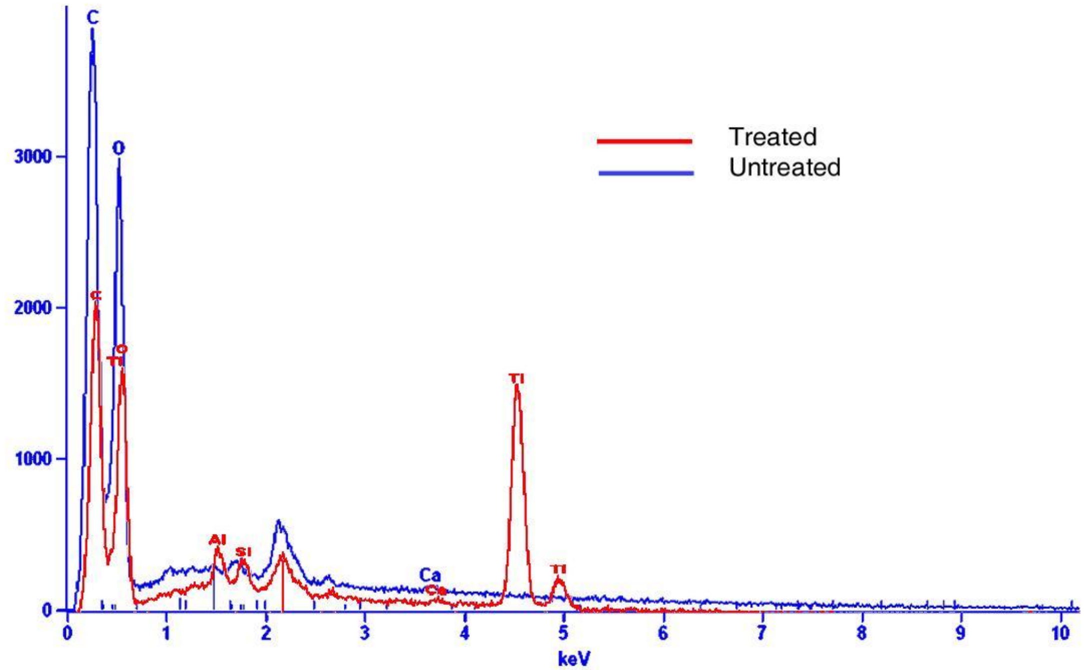

Figure 4 - EDX of untreated and treated sample 2

Quantitative Results for untreated and treated sample 2

Element	Net Counts		Weight (%)		Atom (%)	
	Untreated	Treated	Untreated	Treated	Untreated	Treated
C	37180	19651	60.39	49.22	67.05	62.06
O	25563	15175	39.49	34.16	32.91	32.34
Al	--	2753	--	0.72	--	0.40
Si	--	2872	--	0.70	--	0.38
Ca	328	391	0.12	0.17	0.04	0.06
Ca	0	0	--	--	--	--
Ti	--	22196	--	15.05	--	4.76
Ti	--	1670		--	--	--
Total	--	--	100.00	100.00	100.00	100.00

3.4 Effect of air permeability on treated fabrics

Air permeability values for the untreated sample, treated sample and treated sample after 25 washes are presented in Table 3. It is observed that air permeability of all the treated samples (II) was decreased when compared to the untreated sample (I). This may be due to the finishing treatment applied on these fabrics. After 25 washes (III) of the finished fabric the air permeability was increased when compared to the treated sample only (II). This is due to the fact that after twenty five washes there could be a partial removal of finished chemicals from the treated fabric that facilitates the increase of air permeability.

Table 3 - Effect of UV finish on the air permeability of fabrics

Samples	Air Permeability ($cm^3/cm^2/sec$)		
	I	II	III
Sample 1	275.16	220.12	245.17
Sample 2	249.1	210.97	235.14
Sample 3	134.55	110.41	132.25
Sample 4	124.55	105.47	115.32
Sample 5	73.64	60.5	62.3

I. Untreated Sample II. Finished Sample III. Washed (25) sample

3.5 Effect of absorbency on treated fabrics

The absorbency values of untreated sample, treated sample and treated sample after 25 washes are presented in Table 4. It is seen that there was more time taken for the absorbency of all the treated samples (II, & III) compared to the untreated sample (I). This is because the finishing treatment on these fabrics slightly reduces the hydrophilic character of the fibers and leads to reduced absorbency. However, the absorbency of the treated fabrics was increased after twenty five washes (III) when compared to the treated sample only (II). This increase in absorbency for the washed fabric is due to the partial removal of finished chemicals from the surface of the treated fabric.

Table 4 - Effect of UV finish on the absorbency of fabrics

Samples	Drop Absorbency (sec)		
	I	II	III
Sample 1	3	7	5
Sample 2	47	58	51
Sample 3	55	66	60
Sample 4	60	75	68
Sample 5	80	89	84

I. Untreated Sample II. Finished Sample III. Washed (25) sample

3.6 Effect of wicking on treated fabrics

The wickability of untreated sample, treated sample and treated sample after 25 washes are given in Table 5. It is observed that the wickability of all the treated samples (II & III) was decreased compared to the untreated fabric (I). The decrease in wicking for the finished fabric is due to the reduction of affinity after finishing. After 25 washes (III), the wickability increases when compared to the treated sample (II). This may be due to the partial removal of finished chemicals from the treated fabric which enhances the wickability through the fibers.

Table 5 - Effect of UV finish on the wickability of fabrics

Samples	Wicking (cm)		
	I	II	III
Sample 1	15	10.6	12.2
Sample 2	3.4	3.7	3.5
Sample 3	3.9	3.4	3.8
Sample 4	3.5	3.1	3.3
Sample 5	2.5	2.2	2.3

I. Untreated Sample II. Finished Sample III. Washed (25) sample

3.7 Effect of tensile strength on treated fabrics

The tensile strength of untreated, treated and treated sample after 25 washes are presented in Table 6. After UV finish, a slight variation is observed for the treated sample. However, the loss of tensile strength is not substantial. The tensile strength increases slightly for the treated sample after 25 washes.

Table 6 – Effect of UV finish on the tensile strength of fabrics

Samples	Tensile strength (g)					
	I		II		III	
	Warp	Weft	Warp	Weft	Warp	Weft
Sample 1	595.2	576	371.2	294.4	390.6	302.2
Sample 2	454.4	512	369.6	339.2	388.5	350.2
Sample 3	377.6	460.8	320	230.4	345.2	254.2
Sample 4	390.4	416	275.2	204.8	288.7	222.6
Sample 5	435.2	454.4	268.8	294.4	272.2	296.5

I. Untreated Sample II. Finished Sample III. Washed (25) sample

3.8 Effect of crease recovery angle on treated fabrics

The crease recovery angle of untreated, treated and treated sample after 25 washes are presented in Table 7. It is observed that the crease recovery angle of all the treated samples (II & III) increased when compared to the untreated fabric (I). After 25 washes (III), the crease recovery angle decreases when compared to the treated sample (II). This may be due to the partial removal of finished chemicals from the treated fabric which enhances the crease recovery.

Table 7 - Effect of UV finish on the crease recovery of fabrics

Samples	Crease recovery angle (deg)					
	I		II		III	
	Warp	Weft	Warp	Weft	Warp	Weft
Sample 1	110	105	103	100	108	115
Sample 2	110	120	108	114	118	114
Sample 3	110	115	106	105	108	117
Sample 4	109	114	103	100	105	107
Sample 5	100	110	94	101	98	108

I. Untreated Sample II. Finished Sample III. Washed (25) sample

3.9 Effect of drapability coefficient on treated fabrics

Drape coefficient for the untreated, treated and treated sample after 25 washes are given in Table 8. It is observed that drapability of the treated samples (II) decreased when compared to the untreated sample (I). This may be due to the finishing treatment applied on these fabrics. After 25 washes (III) of the finished fabric the drapability increased when compared to the treated sample only (II). However, the variation in drapabilty is not very significant after finishing.

Table 8 – Effect of UV finish on the drapability of fabrics

Samples	Drape coefficient		
	I	II	III
Sample 1	0.7842	0.8647	0.8124
Sample 2	0.7851	0.8841	0.8171
Sample 3	0.7946	0.8934	0.8283
Sample 4	0.7982	0.8947	0.8826
Sample 5	0.8638	0.9351	0.8963

I. Untreated Sample II. Finished Sample III. Washed (25) sample

4. Conclusions

The performance of titanium dioxide as a UV finish can be efficiently imparted through the application of TiO_2 on the surface of silk and lyocell union fabrics. The UV tests indicate a significant improvement of the UV absorbing activity of the TiO_2 treated fabrics. Such positive results indicate the use of UV resist silk and lyocell fabric for protecting the body against solar radiation. These treatments were durable up to 25 washes. Out of all the samples, Sample 2 performed better with respect to UV finish and its effect on air permeability, absorbency, wicking, drape and tensile strength. It can be concluded that the silk and lyocell union fabric has responded well to UV finish and commercialization of the fabric with UV finish is a novel idea.

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