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A Study of Anti-odor and UV-protection Behavior on Silk and its Polyester / Lyocell Mixed Fabric

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ABSTRACT

Silk and lyocell are natural protein and cellulose polymeric materials. They are important in the fields of textile, apparel and garment. Polyester (PET) is one of the synthetic textiles with very good resistance towards chemical and microbial attacks. In this study it is decided to mix silk with polyester and lyocell. The fabric is then dyed with both natural dyes (kum, indigo, bar berry) and synthetic dyes (reactive dye (H), reactive dye (M) and Sulphur dye). This mixed fabric is compared with 100% silk for the k/s value, fastness properties, drapeability, thermal resistance, anti-odor and uv-protection behaviors. The silk mixed fabric gives very good results compared with the 100% silk fabric.

Keywords: Silk, lyocell, k/s value, anti-odor, uv-protection

Introduction

The natural silk fiber protein is synthesized by silk gland cells and stored in the lumen of the silk glands. Insects mainly belong to two families, *viz*., Saturnidae and Bombycidae, which spins silk fiber. *Bombyx mori* belongs to Bombycidae produces a delicate twin thread of silk fibroin, which is coated by a protective cover of sericin. The varieties of silk fiber produce by these insects are known as mulberry, tasar, muga and eri respectively. The tasar, eri and muga varieties of silk are also known as non-mulberry silk[1]. A single cocoon may provide over 1000 m of fiber by a simple process known as reeling that essentially consists of immersing the cocoon in boiling water[2,3]. The silk fibers obtained from silkworm have two major protein constituents. Core is made of fibroin protein which is surrounded by outer sericin protein[4]. The core fibroin is made up of two chains known as heavy chain and light chain, mainly constitute of alanine, tyrosine and glycine[5,6]. Silk proteins are natural polymers and are biodegradable with reactive functional groups that open up possibility to be cross-linked with other polymers to be used in controlled delivery[7]. The polymer chains of silk fibroin form β-sheet structure. Silk fiber is highly crystalline in nature[8]. The mechanical strength of silk fiber is in the range of 1.9-5.2 g/den. Silkworm is being used as biofactory for the production of useful protein[9]. When the silkworms secrete the liquid silk during the spinning, it passes through the anterior gland and expelled out through the spinneret opening[10]. The silk fiber is thin, long, light and soft. It is well known for its water absorbency, dyeing affinity, thermo tolerances, insulation properties and luster[11]. Silk contains many advantageous properties of the luxurious, lightweight, dyes in beautiful and rich colors, absorbent, strong, moderately wrinkle resistant, resists mildew and moths and does not melt[12]. But silk has the following limitations: weakened by sunlight, perspiration and chlorine bleach, absorbs body oils and grease stain, water spots, yellows and fades with age, subject to attack by carpet beetles unless treated, affected by high temperatures, loses strength when wet, should be pressed with a press cloth, color damaged by hair spray, and damaged by perfumes[13].

Lyocell is defined as a cellulosic fiber that is produced by regenerating cellulose into fiber form out of solution in an organic solvent[14]. It is 100% natural in origin as it is made from wood pulp and is fully biodegradable[15]. The characteristic properties of lyocell are soft handle, luster and moisture absorbency that makes it suitable for a blend or a union fabric [16]. Lyocell fibers offer; absorbent, cool, comfortable to wear, durable, economical and does not melt. It has some limitations also: wrinkles unless treated, susceptible to mildew and strong acids, and may scorch[15, 16]. Polyester materials are good in wrinkle resistance, retains heat-set pleats and creases, superior wash-wear performance, resists damage from abrasion, strong sunlight, weather conditions, moths, mildew and most strong chemicals[17, 18]. Polyester materials have some limitations such as; accumulates static electricity, absorbs body oils, may pill and attract lint, absorbs perspiration odor and melts if too hot[19, 20]. The present study focused on the development of silk mixed fabric (silk warp) and lyocell & polyester (weft). The fabrics were dyed using both natural dyes (indigo, kum kum & bar berry) and synthetic dyes (reactive (M), reactive (H) & sulphur) and the dyed fabrics were subjected to different tests such as k/s value, fastness properties, drapeability, thermal resistance, anti-odor and uv-protection behaviors. The results obtained are in appreciable manner particularly for sarees relevant with 100% silk.

Materials and Methods

Materials

The two types of fabrics (1. 100% silk (both warp & weft) and 2. Silk (warp 100%) and 50% lyocell and 50% polyester (weft) mixed fabrics) were used as mentioned in the following Table (i).

Table (i). Fabric details

S. No.	Parameters	100% Silk	50% Silk+ 50% polyester & lyocell
1	Warp Count	2/80^s	Silk : 2/80^s
2	Weft Count	2/80^s	Polyester and Lyocell (50 : 50) : 2/80^s
3	Ends / Inch	100	100
4	Picks / Inch	60	60
5	GSM	95	95
6	Cloth Width (Inch)	44	44

Natural dyes (kum kum, indigo, bar berry) and synthetic dyes (reactive dye (M), reactive dye (H) and sulphur dye) used were in the commercial grade. The chemicals and auxiliaries mentioned elsewhere for this study were in AR grade

Methods

Pretreatment on silk and its mixed fabric

The above mentioned materials were treated with 10 gpl hydrochloric acid for 60 minutes in a suitable separate baths with material to liquor ratio 1:30 at 30ºC to get rid of the substrates added during weaving.

Dyeing of silk and its mixed fabric

The silk and its mixed fabric were dyed with natural (indigo, kum kum & bar berry) and synthetic (reactive dye (M), reactive dye (H) and sulphur dye) dyes. Dyeing was carried out at boil for two hours with a material to liquor ratio of 1:20 as per the established technique of dyeing for natural and synthetic dyes. The dyed samples were washed, soaped and dried[21, 22].

Measurement of K/S value on dyed silk and its mixed fabric

Color intensities of the dyed silk and its mixed fabrics were measured using spectrophotometer (model: Premier color scan ss 5000 A) within the range of 400-700 nm. Reflectance values were measured and the relative color strength (K/S) was calculated using Kubelka Munk equation [23]. (K/S) defines a relationship between spectral reflectance (R) of sample and its absorption (K) and scattering (S) characteristics. $K/S = \{(1-R)^2/2R\}$.

Color Fastness Test on dyed silk and its mixed fabric

Color fastness of the dyed silk and its mixed fabric to washing, light and rubbing was determined by standard test methods. The results were assessed in ratings from grade 1 (very poor) to grade 5 (excellent). The color change was assessed according to grey scale from grade 1 (much altered) to grade 5 (unaltered).

Wash fastness on dyed silk and its mixed fabric

The wash fastness of the dyed silk and its mixed fabric was determined by IS 764-test 3 method[24]. The fabrics (10×4 cm) were sewed along all four edges with same size of multi-fiber fabric. The composite specimen was washed at 60ºC for 30 minutes using detergent solution 5 g/l maintaining fabric to liquor ratio at 1: 50. The change in color of the specimen and staining of the adjacent fabric were assessed by grey scale.

Light fastness on dyed silk and its mixed fabric

The light fastness of the dyed silk and its mixed fabric was determined by AATCC test method 16E-2004[25]. These dyed fabrics were exposed separately for 10 hours under artificial light source- xenon arc lamp. The color change of exposed portion was compared with masked portion of test specimen.

Fastness to rubbing on dyed silk and its mixed fabric

Color fastness to crocking was determined by AATCC test method 8-2007[26]. AATCC standardized crockmeter was used to determine the rubbing fastness of dyed fabrics under wet and dry conditions to assess the staining property.

Measurement of drapeability of silk and its mixed fabric

Measurement of a fabric's drape on silk and its mixed fabrics is meant to assess its ability to hang in graceful curves. Drape test was carried out using Cusik Drapemeter[27].

Thermal resistance of the dyed silk and its mixed fabric

The thermal resistance, Rth, of textile fabrics [28] is a function of the actual thickness of the material and the thermal conductivity k. This function is given by the following relationship: $Rth = L / k$, ((m2 ºC) /W) where L is the actual thickness of the sample, m.

Organoleptic evaluation of odor control - after 48 hrs. (In house method)

The dyed and finished (**anti-odor finishing agent H9000)** silk and its mixed fabrics were evaluated by six judges. The judges made anti-odor evaluations[29, 30], 14 hours after removal of the sample on each test day. The judges used individual scoring sheets and new sheets were used every day of the evaluation. The odor grading scale was 10 to 0 (“no odor” to “very intense and disagreeable odor”).

UV protection finishing on silk and its mixed fabric

The UV protection finishing (Super FX Anti UV) was given to the dyed silk and its mixed fabric. The finished fabrics were then tested according to the standard method [31, 32].

Results and Discussion

K/S values of dyed silk and its mixed fabric

The colorimetric data of indigo, kum kum, bar berry, reactive dye (M), reactive dye (H) and sulphur dyes applied on silk and its mixed fabric are given in Table 1. It is seen from Table 1 that the silk and its mixed fabric dyed with indigo, kum kum, bar berry, reactive dye (M), reactive dye (H) and sulphur dye show good colorimetric data. The average k/s value for the silk mixed fabric dyed with indigo, kum kum, bar berry, reactive dye (M), reactive dye (H) and sulphur dye is around 14.7 whereas this value is less for 100% silk fabric (around 14.1). The k/s value on silk mixed fabrics for reactive dyes (M & H) is around 14.85 followed by 14.65 (sulphur dye), 14.60 (Indigo), 14.54 (bar berry), and 14.50 (kum kum) respectively. The 100% silk fabric also follows the same trend of colorimetric data, such as, for reactive dyes (M & H) around 14.36 followed by 14.21 (sulphur dye), 14.01(Indigo), 13.95 (bar berry), and 13.70 (kum kum) respectively. From this table it is seen that both the type of fabrics show good values indicating good dyeing. The difference in the k/s values between the two type of fabrics is only marginal. The reason for good dyeing and k/s values is being the reaction between the reactive dye and reactive site of the polymers in the fabric materials. The silk polymer contains multiple functional groups like –OH, $-SO_3H$, -COOH, $-C_6H_5OH$, $-NH_2$. Likewise in lyocell the reactive group –OH is present throughout the polymeric chain. These reactive groups are responsible for the good dyeing and k/s values in silk and silk mixed fabrics. The k/s value around 12 and more than 12 is considered to be good color strength. Hence, the colorimetric data on 100% silk and its mixed fabrics dyed using indigo, kum kum, bar berry, reactive dye (M), reactive dye (H) and sulphur dye are in the accepted value.

Table 1. K/S values of dyed silk and its mixed fabric

S. No.	Dyes	Colorimetric data of silk and its mixed fabric											
		100% Silk						Silk (warp) Polyester & Lyocell (Weft – 50: 50)					
		L*	a*	b*	C	h°	K/S	L*	a*	b*	C	h°	K/S
1	Indigo	26.2	-6.06	-14.41	23.1	262	14.0	37.9	-6.15	-15.30	21.6	251	14.6
2	Kum kum	27.7	-5.84	-15.95	23.5	251	13.7	31.0	-5.98	-15.52	22.0	255	14.5
3	Bar berry	29.5	-5.96	-14.24	22.9	262	13.9	32.0	-5.30	-15.08	21.6	251	14.5
4	Reactive Dye (M)	36.8	-4.65	-16.84	23.0	256	14.3	27.4	-5.30	-14.87	22.1	265	14.8
4	Reactive Dye (H)	36.5	-6.95	-16.62	22.8	253	14.4	35.3	-4.32	-15.15	23.5	241	14.9
6	Sulphur Dye	28.7	-4.75	-16.16	23.5	246	14.2	33.3	-4.62	-15.18	24.0	268	14.7
Mean							14.1	Mean					14.7
Standard Deviation							0.27	Standard Deviation					0.16
Variance							0.07	Variance					0.02

Fastness properties of dyed silk and its mixed fabric

The fastness properties (wash, light and rubbing) of natural and synthetic dyed (indigo, kum kum, bar berry, reactive dye (M), reactive dye (H) and sulphur) dyes applied on silk and its mixed fabric are given in Table 2. The wash fastness of the dyed silk materials is good as compared with other fatnesses like light and rubbing fastness properties. The good wash fastness property is due to the strong reaction between the reactive groups of the polymer in the fabric materials and the also of the dye. It is obvious that the light fastness and rubbing fastness properties are moderate to poor only due to their behavior towards these applications.

Table 2. Fastness properties of dyed silk and its mixed fabric

S. No.	Dyes	Fastness properties of dyed silk and its mixed fabric							
		100% Silk				Silk (warp) Polyester & Lyocell (Weft - 50 : 50)			
		Wash	Light	Rubbing		Wash	Light	Rubbing	
				Dry	Wet			Dry	Wet
1	Indigo	4	4	2	1-2	4	4	2	1-2
2	Kum kum	3	3	3	1-2	3-4	2-3	2-3	1
3	Bar berry	3	3	2-3	1-2	3	3	2-3	1-2
4	Reactive Dye (M)	3-4	3-4	3	2	3	3-4	2-3	1-2
5	Reactive Dye (H)	3-4	3-4	3	1-2	3-4	3-4	2-3	1-2
6	Sulphur Dye	4	4	2	1-2	4	4	2	1-2
Mean		3-55	3-5	2-3	1-2	3-4	3.0	2.0	1.0
Standard Deviation		0.447	0.447	0.492	0.204	0.447	0.585	0.258	0.204
Variance		0.2	0.2	0.242	0.042	0.2	0.342	0.067	0.042

Drape co-efficient of silk and its mixed fabric

Drape is the term used to describe the way of a fabric / saree hangs under its own weight. It has an important bearing on how good a garment looks in use. The draping qualities required from a fabric will differ completely depending on its end use, therefore a given value for drape cannot be classified as either good or bad. Measurement of a fabric's drape is meant to assess its ability to do this and also its ability to hang in graceful curves. The data of drape co-efficient of 100% silk and the silk mixed fabrics are given in Table 3. The silk mixed fabric shows the high drape co-efficient value (0.696) than the value of 100% silk fabric (0.672). The increase in drape value of mixed silk fabric is due to the inclusion of lyocell and polyester material.

Table 3. Drape co-efficient of silk and its mixed fabric

S. No.	Dyes	Drape co-efficient	
		100% Silk	Silk (warp) Polyester & Lyocell (Weft – 50: 50)
1	Indigo	0.662	0.686
2	Kum kum	0.669	0.698
3	Bar berry	0.676	0.696
4	Reactive Dye (M)	0.679	0.705
5	Reactive Dye (H)	0.682	0.708
6	Sulphur Dye	0.661	0.684
Mean		0.672	0.696
Standard Deviation		0.0089	0.0097
Variance		0.00008	0.00009

Thermal resistance of the dyed silk and its mixed fabric

The thermal resistance of dyed (indigo, kum kum, bar berry, reactive dye (M), reactive dye (H) and sulphur dye) silk and its mixed fabric are given in Table 4. Thermal properties of textiles are influenced by fabric properties such as structure, density, humidity, raw materials (fibers), type of weave, surface treatment, filling and compressibility, air permeability, surrounding temperature and other factors. The studies of thermal characteristics have gained importance since it is directly related to clothing comfort. From the Table4, it is seen that the thermal resistance of silk fabric is nearly 5% higher than the silk mixed fabric. The low thermal resistance of silk mixed fabric is due to the presence of lyocell textile which easily dissipates the thermal behavior. Similar to the cotton textile lyocell is also considered fully hydrophilic and contains attractive groups of –OH only which easily reduces the thermal conductivity of the materials.

Table 4. Thermal resistance of the dyed silk and its mixed fabric

S. No.	Dyes	Thermal Resistance (m^2.mk/w) of the dyed silk and its mixed fabric	
		100% Silk	Silk (warp) Polyester & Lyocell (Weft – 50: 50)
1	Indigo	98.26	92.38
2	Kum kum	97.52	92.17
3	Bar berry	97.65	92.23
4	Reactive (M)	97.30	92.11
5	Reactive dye (H)	97.23	92.07
6	Sulphur dye	98.38	92.44
Mean		97.72	92.23
Standard Deviation		0.4876	0.1484
Variance		0.2377	0.0220

Anti-odor behavior of the dyed and finished silk and its mixed fabric

The dyed and finished silk and its mixed fabrics were assessed by subjective evaluation technique performed by six women of different age categories (25 to 50 years) and the odor grading was rated between 0 and 10. Based on the performances of the natural and synthetic dyes the dyeing was carried out on the suitable materials. The data of anti-odor assessment performed are given in Table 5. Table 5 shows that the average anti-odor behavior of silk mixed fabric is 8.7 and that for 100% silk fabric is 8.4. This may be due to fact the silk mixed fabric contains the highly reactive lyocell textile and highly inert polyester which is against any adherence of odor. The overall rating of silk and the silk mixed fabric is between very good (8) to excellent (9).

Table 5. Anti-odor behavior of the dyed and finished silk and its mixed fabrics (assessed by Women)

S. No.	Dyes	Anti-odor behavior											
		100% Silk						Silk (warp) Polyester & Lyocell (Weft – 50: 50)					
		A	B	C	D	E	F	A	B	C	D	E	F
1	Indigo	9	8	9	9	9	8	9	9	9	9	9	9
2	Kum kum	9	8	8	9	8	8	9	9	8	8	9	8
3	Bar berry	9	8	8	8	9	7	9	9	9	8	8	8
4	Reactive dye (M)	9	8	8	9	8	7	9	8	9	8	8	9
5	Reactive dye (H)	8	9	8	8	9	8	9	9	8	9	9	8
6	Sulphur dye	9	9	8	9	9	8	9	9	9	9	9	9
Mean		8.8	8.3	8.2	8.7	8.7	7.7	9	8.8	8.7	8.5	8.7	8.5
Standard Deviation		0.41	0.52	0.41	0.52	0.52	0.52	0	0.41	0.52	0.55	0.52	0.55
Variance		0.17	0.27	0.17	0.27	0.27	0.27	0	0.17	0.27	0.3	0.27	0.3

A → Height – 162 cm ; Weight – 57 Kg, Age → 25 years
B → Height – 170 cm ; Weight – 65 Kg, Age → 30 years
C → Height – 167 cm ; Weight – 70 Kg, Age → 35 years
D → Height – 166 cm ; Weight – 74 Kg, Age → 40 years
E → Height – 166 cm ; Weight – 77 Kg, Age → 45 years
F → Height – 165 cm ; Weight – 78 Kg, Age → 50 years

0 – Repulsive ; 1 – Very Poor ; 2 – Poor ; 3 - Poorly Fair ; 4 – Fair ; 5 – Acceptable ; 6 – Fairly Good ; 7 – Good ; 8 – Very Good ; 9 – Excellent ; 10 – Ideal

Anti-odor retention behaviour and release rate of the dyed and finished silk and its mixed fabric

The concentration of the anti-odor agent was measured by UV / visible spectrophotometer by extracting the anti-odor agent from the finished fabric sample using ethanol. The extracted content was diluted to 1:10 ratio with distilled water. The absorbance of the diluted solution was measured at 206 nm. The release rate of the fragrance was calculated according to the following formula;

$$\text{Release rate of fragrance} = \frac{\text{Immediate conc.} - \text{Conc. After 4 days (or 8 days)}}{\text{Immediate conc.}} \times 100$$

The data obtained is given in Table 6 (11% silk) and Table 6(a) (silk mixed fabric) respectively. From theses tables it is noticed that the anti-odor retention behavior is very good even after its test in 4 days and 8 days. The release rate of anti-odor agent from the fabrics is subsequently increased from the average of 8% for 4 days to nearly 20% for 8 days in both 100% and silk mixed fabrics. All the dyed fabrics irrespective of 100% silk or silk mixed fabrics give uniformly good anti-odor retention behavior as evidenced in the very less difference of standard deviation and variance.

Table 6. Antiodour retention behaviour and release rate of the dyed and finished silk fabric

S.No.	Dyes	Retention of anti-odor agent on the fabrics (mg/g)			Release rate of anti-odor agent from the fabrics (%)	
		Immediately	After 4 days	After 8 days	After 4 days	After 8 days
1	Indigo	312.48	288.93	251.74	7.7	19.5
2	Kum kum	311.24	285.76	249.33	8.0	19.9
3	Bar berry	311.16	285.34	249.15	8.4	19.9
4	Reactive (M)	311.93	286.94	250.22	8.0	19.9
5	Reactive dye (H)	311.85	287.58	250.83	7.7	19.6
6	Sulphur dye	312.46	288.84	251.62	7.6	19.5
Mean		311.85	287.23	250.48	7.9	19.72
Standard Deviation		0.57	1.51	1.11	0.30	0.20
Variance		0.33	2.28	1.23	0.09	0.04

Table 6(a). Anti-odor retention behaviour and release rate of the dyed and finished silk mixed fabric

S.No.	Dyes	Retention of anti-odor agent on the fabrics (mg/g)			Release rate of anti-odor agent from the fabrics (%)	
		Immediately	After 4 days	After 8 days	After 4 days	After 8 days
1	Indigo	309.81	283.42	246.15	8.5	20.5
2	Kum kum	308.41	279.94	243.51	9.2	21.0
3	Bar berry	308.22	279.63	243.37	9.3	21.0
4	Reactive (M)	308.62	280.86	244.62	9.0	20.7
5	Reactive dye (H)	308.74	281.35	244.24	8.8	20.9
6	Sulphur dye	309.28	283.58	245.91	8.4	20.5
Mean		308.85	281.46	244.63	8.9	20.8
Standard Deviation		0.59	1.69	1.18	0.37	0.23
Variance		0.35	2.87	1.39	0.14	0.05

UV Protection factor for reactive dyed and UV protection finished silk and its mixed fabric

The UV transmittance of the dyed and finished fabrics (100% silk and silk mixed fabrics) were determined using UV visible spectrophotometer. The standard chart for determining the UV protection factor is presented in the Table 7, and the data of UV protection factor for these fabrics are given in Table 7(a).

The UV protection factor for the silk and silk mixed fabrics is given in Table 7(a). The UV protection factor (UPF) values of all the dyed and finished fabrics are between 35 and 39 respectively. The maximum UPF value (39) is given by the silk mixed fabrics dyed with indigo (natural dye) and reactive and sulphur (synthetic dyes); whereas the minimum UPF value (36.5) is seen in 100% silk fabrics dyed by kum kum, barberry (natural dyes) and reactive (synthetic dye) From these data (Tables 7 & 7(a)) it is clear that there is a very good UV protection category as revealed by UPF rating (35 – 39) for the dyed and finished silk and silk mixed fabrics. Therefore based on this, as indicated in the table 7(a) the percent UV radiation blockage by these fabrics (dyed and finished silk and silk mixed fabrics) would be between 96% and 97.4%.

Table 7. Standard chart for UPF rating for the fabric

UPF Rating	Protection Category	% UV Radiation Blocked
15 to 24	Good	93.3 - 95.9
25 to 39	Very Good	96 - 97.4
40 to 50	Excellent	97.5 or more

Table 7(a). UV Protection factor for the dyed and uv protection finished silk and its mixed fabric

S. No.	Dyes	UPF rating of the dyed and finished fabrics	
		100% Silk	Silk (warp) Polyester & Lyocell (Weft – 50: 50)
1	Indigo	37	39
2	Kum kum	36	38
3	Bar berry	36	38
4	Reactive (M)	37	38
5	Reactive dye (H)	36	39
6	Sulphur dye	37	39
Mean		36.5	38.5
Standard Deviation		0.55	0.55
Variance		0.3	0.3

Conclusions

From this research work on 100% silk and silk mixed fabric dyed with natural dyes (indigo, kum kum & bar berry) and synthetic dyes (reactive (M), reactive (H) & sulphur), the following conclusions are arrived;

The k/s values are mostly similar in both the 100% silk fabric and silk mixed fabric, but the fastness properties (wash, light and rubbing) are quite less in the silk mixed fabrics due to the presence of polyester material. The overall fastness property is more for washing compared with the corresponding light and rubbing.

The silk mixed fabric gives good drape co-efficient value which is an appreciable comfort character for a garment to feel better. The thermal resistance of silk mixed fabric is low compared with 100% silk fabric and that leads to give good clothing comfort.

The anti-odor behavior of silk mixed fabric and that of 100% silk fabric is excellent to very good. Similarly the anti-odor retention behavior of these fabrics is also very good. There is a very good UV protection category for the dyed and finished silk and silk mixed fabrics.

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Plate: View of the commercially produced Silk mixed (Polyester & Lyocell) Saree