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ENHANCING THE PROTECTION PROPERTY ON SILK FABRIC BY THE TREATMENT OF POLYACRYLIC ACID AND CHITOSAN

E. Saraswathi [1], J. Jeyakodi Moses [2]

[1] Ph.D. Research Scholar, Research and Development Centre, Bharathiar University, Coimbatore 641046, India
[2] Associate Professor, Department of Applied Science, PSG College of Technology, Coimbatore 641004, India

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Corresponding Author

J. Jeyakodi Moses,
jjmoses2k2@gmail.com

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ABSTRACT

Silk is valued as one of the prominent protein textile fibers under the animal category famous for the distinct properties such as lustrous appearance, comfort performance, remarkable shiny sheen and also towards the bio-applications. In general, silk is highly sensitive and delicate; hence, there is a need for the protection in order to protect silk from the unwanted impacts of chemicals, light and insects. According to this consideration, in this work it is decided to give an application with polyacrylic acid (PA) and chitosan (CT) followed by adopting coloration process using selected natural dyes and a synthetic reactive dye. The silk fabric samples were undergone to specific tests like measuring the common physical properties, color values and the respective fastness aspects, hand values, antibacterial, uv protection performances and FTIR studies. The outcome of the results give very considerable improvement towards the protection aspects for the silk fabric specific for the textiles / garments and other utility products.

Keywords: Silk Fabric, Polyacrylic Acid, Chitosan, Natural Sources, Anti-Bacterial, UV Protection

1. INTRODUCTION

Silk is valued as the prominent textile fiber under the protein category obtained from the silkworm. The leading properties of silk lead for elegant appearance, wearing comfort, good air permeability, soft handle, brilliant color shades and make it as the symbol of royalty Koh et al. (2015), Li et al. (2013). In the chemical structure of the silk filament, varied chemical components are present; fibroin [75%], sericin [22.5%], mineral salt [0.5%], fat & wax [1.5%], and ash content [0.5%], in which fibroin comprises sixteen different amino acids. Fibroin produces two filaments as composed in the raw silk and they are cemented together by the gum – Sericin Chen et al. (1994), Asakura et al. (2001), Robson (1985). In order to remove the gum substances and other related unwanted things, the process called degumming is adopted Hiroshi (1999), Pak (1977). In spite of the presence of maximum of the textile properties such as heat conductivity, absorbency, cleanliness & wash ability, tensile strength & elasticity, resilience & drape ability, heat & light resistance, mildew & insects resistance and dye affinity; some issues in functional performances like, crease recovery, photo-yellowing, colorfastness to dry and / or wet rub fastness, perspiration fastness limits the traditional applications in the textile product utilities. Kaplan et al. (1993), Cheung et al. (2009).

Silk is basically regarded as a delicate textile material and mostly valued for the luxurious and virgin character for its bright colors, gloss, rarity, and smoothness Hojo (2000),Voegeli et al. (1993). Silk is basically a natural protein textile material developed through the moth larva called *Bombyx mori,* that are conventionally cultivated*.* Other types of silk fibers are also available, namely the *Tussah silk* that is considered as the wild silk since they could not be developed domestically Senand Babu (2004), Vepari and Kaplan (2007), Furuzono et al. (2000), Xing et al. (2012). Prior to the emergence of the synthetic textile fiber materials, in the preparation of royal clothing, special occasion garments, interior home textiles such as embroideries & ecclesiastical and functional products silk was mostly preferred. The affinity of silk towards natural dyeing gives shining and bright colors that was highly considered particularly in association with the red dyes for promoting the royal identity. The red shades were also developed such as the royal and sacred deep red cochineal, the delicate glistening safflower pink and the sweet orange madder red Shin (2008), Liu and Wang (2011).

Silk is famous for its lustrous, soft, and delicate character. However, on exposure to different chemicals, insects, and sunlight at higher levels, silk is easily damaged due to its sensitiveness. Hence, it is highly essential to protect the valuable silk materials from these damages. Based on these criteria, in this research work, it is decided to give the application on silk fabric with polyacrylic acid and chitosan Rinaudo (2006), Kaş (1997), Guo et al. (2010), Gao et al. (2000) followed by coloration with selected natural coloring sources and a synthetic reactive dye Shin (2008), Liu and Wang (2011). The results received from this study reveal that the silk fabric treated with polyacrylic acid and chitosan followed by the natural coloration process increases the overall performances suitable for the textile and garment end use products.

2. MATERIALS AND METHODS

2.1. MATERIALS

From the Vadavalli - Sarvodaya Sangam (Coimbatore, India), the mulberry silk fabric (100% raw, plain, woven) was received. From the Coimbatore - Forest department, India, the natural sources were collected. From the commercial dye shop (Thiruppur, India), the reactive dye (Reactive yellow HE6G) was obtained. The Table 1 gives the brief descriptions about these materials. From the local scientific company, the commercial polyacrylic acid (PA) and chitosan (CT); and all auxiliaries and chemicals involved in this work were obtained in analytical grade.

Table 1

Table 1 Utilization of Involved Sources				
S. No.	**Mulberry Silk Woven Fabric**		**Coloring Ingredients**	
	Categories	**Values**	**Natural Sources (*Botanical name*)**	**Color Obtained**
1	Warp Count	2/80s	Kum kum (*crocus sativa*)	Yellow
2	Weft Count	2/80s	Bar berry (*berberis vulgaris*)	Yellow
3	Ends / Inch	100	Annatto (*bixa orellana*)	Orange
4	Picks / Inch	60	Onion (*allium cepa*)	Red Orange
5	GSM	95	Red Sandalwood (*pterocarpus santallinus*)	Orange Red
6	Cloth Width (Inch)	44	Grape (*citrus paradise*)	Purple
7			Madder (rubia cardifolia)	Red
8			Reactive yellow HE6G (C.I. Name: *Reactive yellow 135*)	Yellow

2.2. METHODS

2.2.1. PRELIMINARY TREATMENT ON RAW SILK FABRIC

10 gpl hydrochloric acid (HCl) was subjected on the raw silk fabric for 60 minutes in a suitable hot water bath with MLR (material to liquor ratio) 1:30 at ambient temperature (30oC) so as to remove the unwanted substrates. Then degumming process was performed on the silk fabric in mild alkaline condition (using sodium carbonate and degum detergent) at 85oC for two hours. The degummed silk fabric was finally rinsed thoroughly using de-ionized water and then dried Gulrajani (1988), Sargunamani and Selvakumar (2002), Yang et al. (2013), Krysteva et al. (1981).

2.2.2. SILK FABRIC TREATMENT WITH PA

The PA (polyacrylic acid) (concentration of 1%, 2%, 3.0%, 4%, 5%, 6.0% w/v) in 0.25 N sodium hydroxide was applied on the degummed silk fabrics for 30 minutes. The treated silk fabrics were then pressed, dried at 105oC for 30 minutes, and cured at 140oC for 60 seconds. At last, the PA treated silk fabrics were washed, and dried.

2.2.3. SILK FABRIC TREATMENT WITH CT

The CT (chitosan) (concentration of 1%, 2%, 3.0%, 4%, 5%, 6.0% w/v) was subjected with 2% acetic acid solution separately for dissolution and filtered before application Rinaudo (2006), Kaş (1997). The silk fabric samples were immersed into the chitosan bath and the pH was set at 5.0±0.2 with glacial acetic acid. The temperature of the chitosan bath was set at 95oC and the CT treatment on silk fabric was preceded for 30 minutes at this condition. The treated samples were conditioned, thoroughly rinsed with warm water followed by cold water and then dried.

2.2.4. SILK FABRIC DYEING

The silk fabrics dyeing was carried out using selected natural sources and a reactive dye. The dyeing process was carried out with the selected concentration of

25 gram per litre for natural dyes and 2% on weight of the material for reactive dye at boil for around two hours with a material to liquor ratio of 1:20 as per the referred technique of dyeing with respect to natural and synthetic dyes Gulrajani (1988), Broadbent (2001), Lewis (2011).

2.2.5. COLOR STRENGTH AND FASTNESS PROPERTIES DETERMINATION AFTER SILK FABRIC DYEING

Kubelka Munk equation was used to calculate the color strength value in order to have the relationship between the spectral reflectance of the silk fabric sample and the respective absorption, K and scattering, S characteristics; K/S = {(1-R) 2/2R} Broadbent (2001), Mourad et al. (2001). The established standard procedures were used to determine the wash fastness, light fastness, crocking / rubbing fastness of the treated and dyed silk fabrics AATCC Test Method 61-1996. (2003), A. A. T. C. C. Test Method 16.-1998 (2003), A. A. T. C. C. Test Method 8. (2007), A. A. T. C. C. Test Method 135-1985 (2003).

2.2.6. PHYSICAL PROPERTIES OF THE SILK FABRIC

The silk fabrics were subjected for the measurement of physical properties, namely, tensile strength, elongation, drapeability, thermal resistance, and stiffness as mentioned in the standard established methods Koh et al. (2015), Kothari (1999).

2.2.7. KES-F OBJECTIVE ASSESSMENT ON THE SILK FABRIC

The silk fabrics were assessed by the Kawabata evaluation system (KES-F) for getting the important listed surface and mechanical properties Kawabata and Niwa (1991).

2.2.8. ASSESSMENT OF ANTI BACTERIAL TEST ON THE SILK FABRIC

The silk fabrics were subjected for the agar diffusion test (SN 195920) and the respective modified Hohenstein (JIS L 1902) test. The organisms used in both the tests were Staphylococcus aureus and Escherichia coli Gao and Cranston (2008), Liu et al. (2016), Gouda and Hebeish (2010), A. A. T. C. C. Test Method 147. (2004).

2.2.9. ASSESSMENT OF UPF ON THE SILK FABRIC

The uv protection factor (UPF) determination on the silk fabric samples were carried out by subjecting the samples with uv protection finishing (Super FX Anti UV) agents and subsequently tested according to the standard method Mongkholrattanasit et al. (2011), Djam et al. (2011), Bajaj et al. (2000).

2.2.10. SILK FABRIC ANALYSIS BY FTIR STUDY

The silk fabric samples were subjected for the Fourier Transfer Infra-Red (Shimadzu, Japan) spectrophotometer study towards the analysis of the suitable functional groups Shao et al. (2005), Oh et al. (2005).

3. RESULTS AND DISCUSSION

3.1. PHYSICAL PROPERTIES OF PA AND CT TREATED SILK FABRICS

The silk fabric samples with PA treatment, CT treatment, and no treatment, are tested for the conventional physical properties namely, tensile strength & elongation, stiffness / bending modulus value, drape co-efficient, and thermal resistance; and the results are presented in Table 2. Similar to that, in Table 1a, the related values for the treated fabrics after dyeing are presented. For the optimization of concentration and time, based on the trials carried out, the PA and CT treatments on the silk fabrics are finalized. In the trials carried out earlier, PA and CT treatments were given on the silk fabrics with the concentration started from 1.0% (w/v) to 6.0% (w/v) with different time duration from five minutes to sixty minutes with the step increase of 1.0. From those trials, it was noted that the PA and CT treatments on silk fabric samples gave favourable results at the time duration of 30 minutes. Therefore, the application of the PA and CT on the silk fabric samples were optimized by the concentration of 1.0% w/v to 6.0% w/v for thirty minutes only for all the treatments and the respective results are shown in the Table 2. It is noted from the Table 2 that there is a linear change in the physical properties when the treatment concentrations of PA and CT on the silk fabric increases. The textile material under the stress with the deformation of high extent of homogeneous material stress reveals tensile strength. When comparing the tensile strength of the silk fabric without treatments with the PA and CT treated fabrics the latter one shows substantial increase over the former. The increase of tensile strength as an average for both warp and weft of silk fabric treated with PA and CT over that of untreated one is around 8% and 10% respectively. The CT treated silk fabrics have the edge of around 3% increase over that of the PA treated one for both the average of warp and weft tensile strength. When compared with the weft tensile strength, the warp tensile strength of silk fabric is considerably high. There is a significant increase in the warp and weft tensile strength upto 4% w/v respectively, when the concentration of PA and CT increases, however afterwards there is an insignificant increase only.

When elongation (%) is considered, the difference is only marginal and there is a decrease in the tune of maximum of average 3% only among the PA, CT, and no treated silk fabrics. With regard to stretching, there is considerable increase in length or deformation favoured as elongation in a textile fiber. Elongations are needed for selective textile materials like corsetry and stretch products. There is no much influence (only around 1.0%) in the silk fabric samples after the PA and CT treatment in the case of the drape coefficient. The way of a textile fabric hangs with respect to the own weight is described by the term drape. With regard to the requirement of the end use, the qualities of draping needed from a textile fabric will completely change. The thermal resistance values of the PA and CT treated silk fabric samples do not give the impact; in all the cases the values are almost retained around 98 (m2.mk/w). The thermal characteristics knowledge of the textile fabric has received more importance which is related to clothing comfort directly. When comparing with the untreated one, the bending modulus of the PA and CT treated silk fabrics show nearly one-fold increase. The thicker the fabric, the stiffer it is when all the other related factors retained to be the same. Relative increase of the bending length promotes the stiffness of the fabric. It is seen from the Table 2 that the physical property values are considerable high for the silk fabrics treated with PA and CT up to the strength 4% w/v beyond that the change is insignificant. Based on this, the application of PA and CT on the silk fabric samples is optimized with the strength of 4% w/v for thirty minutes; and this component is fixed and proceeded for the further works. The silk fabric samples were dyed with some selected natural dyes such as kum kum, bar berry, annatto, onion, red sandal wood, grape, and madder and a synthetic reactive yellow dye after the PA and CT treatments of 4% w/v for 30 minutes. The respective physical properties of them were carried out and the values are shown in Table 3. As discussed with the Table 2, the values in Table 3 also follow the similar trend. When compared with that of PA and CT treated and dyed silk fabrics, the difference is significant only for the untreated silk fabric samples. There is only insignificant change between the PA and CT treated dyed silk fabric samples considering for their physical property aspects.

Table 2

Table 2 Physical Properties of PA and CT Treated Silk Fabrics

Concentration of Chemicals (%w/v)		0	1.0		2.0		3.0		4.0		5.0		6.0	
Time (sec)		0	30		30		30		30		30		30	
Testing		**Physical Properties of Treated Silk Fabrics**												
Parameters		NO	PA	CT	PA	CT	PA	CT	PA	CT	PA	CT	PA	CT
Tensile Strength (Kgf/mm 2)	**Warp**	55.1	58.2	60.8	59.2	61.6	59.6	62.0	61.2	63.8	61.3	63.9	61.4	64.0
	Weft	47.9	51.1	53.3	51.3	53.6	51.9	54.2	53.9	56.2	53.9	56.3	54.0	56.3
Elongation (%)	**Warp**	16.7	16.6	15.6	16.2	15.6	15.8	15.2	15.0	14.4	14.9	14.3	14.8	14.2
	Weft	15.8	15.6	15.0	15.3	14.7	14.9	14.3	14.0	13.4	13.9	13.3	13.8	13.2
Stiffness / Bending Modulus Value		0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Drape Co-efficient		0.68	0.68	0.67	0.68	0.67	0.67	0.66	0.67	0.66	0.67	0.65	0.66	0.65
Thermal Resistance (m^2.mk/w)		98.9	98.8	98.7	98.7	98.6	98.5	98.4	97.9	97.8	97.8	97.7	97.8	97.7

Table 3

Table 3 Physical Properties of PA and CT Treated dyed Silk Fabrics

Natural Coloring Sources →		(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
Testing Parameters		**Physical Properties of PA Treated Dyed Silk Fabrics**							
Tensile Strength (Kgf/mm2)	**Warp**	63.25	63.32	63.48	63.29	63.37	63.42	63.27	63.53
	Weft	55.67	55.77	55.82	55.74	55.86	55.84	55.79	55.93
Elongation (%)	**Warp**	14.0	14.3	14.2	14.3	14.6	14.3	14.2	14.8
	Weft	13.0	13.3	13.2	13.4	13.6	13.3	13.4	13.9
Stiffness / Bending Modulus Value		0.0021	0.0023	0.0022	0.0021	0.0021	0.0022	0.0021	0.0023
Drape Co-efficient		0.668	0.666	0.667	0.668	0.667	0.666	0.667	0.669
Thermal Resistance (m^2.mk/w)		97.83	97.82	97.82	97.81	97.80	97.83	97.81	97.81
Natural Coloring Sources →		(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
Testing Parameters		**Physical Properties of CT Treated Dyed Silk Fabrics**							

Tensile Strength (Kgf/mm2)	**Warp**	65.85	65.87	65.86	65.85	66.17	65.88	65.86	66.47
	Weft	57.86	57.22	57.98	57.37	57.44	57.97	57.79	58.12
Elongation (%)	**Warp**	13.7	13.9	14.1	13.9	14.0	14.1	13.9	14.2
	Weft	12.7	13.0	12.9	13.1	12.9	13.1	13.0	13.2
Stiffness / Bending Modulus Value		0.0024	0.0024	0.0025	0.0025	0.0024	0.0025	0.0024	0.0027
Drape Co-efficient		0.655	0.654	0.654	0.656	0.655	0.654	0.655	0.657
Thermal Resistance (m^2.mk/w)		97.78	97.77	97.78	97.79	97.78	97.77	97.78	97.81
Natural Coloring Sources →		(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
Testing Parameters		**Physical Properties of Dyed Silk Fabrics (NO Treatment)**							
Tensile Strength (Kgf/mm2)	**Warp**	58.35	58.76	58.54	58.47	58.68	58.59	58.62	58.78
	Weft	51.09	51.37	51.15	51.14	51.18	51.15	51.17	51.39
Elongation (%)	**Warp**	15.9	15.2	15.3	15.1	15.2	15.4	15.3	15.6
	Weft	14.3	14.4	14.2	14.3	14.4	14.2	14.3	14.8
Stiffness / Bending Modulus Value		0.0014	0.0014	0.0015	0.0015	0.0014	0.0014	0.0014	0.0015
Drape Co-efficient		0.676	0.675	0.673	0.674	0.676	0.674	0.674	0.676
Thermal Resistance (m^2.mk/w)		98.11	98.20	98.15	98.18	98.16	98.21	98.19	98.22
(a) → Kum kum, (b) → Bar berry, (c) → Annatto, (d) → Onion, (e) → Red Sandal Wood, (f) → Grape, (g) → Madder, and (h) → Reactive dye									

PA – Polyacrylic Treated, CT – Chitosan Treated, NO – No Treatment Silk Fabrics

3.2. COLORIMETRIC VALUES OF PA AND CT TREATED DYED SILK FABRICS

The results of the colorimetric values of silk fabric with no treatment, PA and CT treatments and then dyeing with natural dyes and synthetic reactive dye are presented in Table 4. In this table, in is clearly noted that the colorimetric data of PA and CT treated dyed silk fabrics are convincingly high compared with those of the no treated and dyed silk fabric. The increment in the colorimetric values observed for the respective PA and CT treated dyed fabrics compared with those of untreated dyed one is in the av. of 13 percent and 15 percent. When compared these values between PA and CT treated dyed silk fabrics, there is an increase of around 1.5% for the latter one. With respect to the application of PA and CT on the silk fabrics, there is an increased presence of reactive groups, and they are considered to be the reason in the enhancement of colorimetric values compared with that of the untreated one.

Table 4

Table 4 Colorimetric Data of PA and CT Treated Dyed Silk Fabrics

Natural Coloring Sources →	**(a)**	**(b)**	**(c)**	**(d)**	**(e)**	**(f)**	**(g)**	**(h)**
Colorimetric Parameters	**Colorimetric Data of PA Treated Dyed Silk Fabrics**							
L*	34.3	35.5	35.2	29.2	33.1	34.9	35.6	35.3
a*	-4.9	-5.8	-5.9	-5.9	-4.0	-4.5	-5.8	-4.3
b*	-16.6	-14.7	-16.2	-14.5	-15.3	-15.9	-14.6	-15.2
C	21.2	22.6	23.2	22.2	21.7	21.4	22.9	23.5
h°	257	258	246	249	254	258	245	241

K/S	14.6	14.5	14.6	14.9	14.3	14.0	14.6	14.9
Natural Coloring Sources →	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
Colorimetric Parameters	**Colorimetric Data of CT Treated Dyed Silk Fabrics**							
L*	34.6	33.9	35.3	34.9	36.9	35.7	35.6	32.2
a*	-5.6	-6.9	-5.7	-5.1	-5.4	-5.8	-6.8	-6.3
b*	-15.9	-15.3	-15.1	-17.9	-16.4	-15.3	-17.6	-16.3
C	21.6	23.6	22.7	22.1	23.3	22.3	23.7	21.6
h°	259	258	253	259	256	256	248	253
K/S	14.7	14.5	14.7	14.9	14.5	14.3	14.7	14.9
Natural Coloring Sources →	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
Colorimetric Parameters	**Colorimetric Data of Dyed Silk Fabrics (NO Treatment)**							
L*	33.3	33.6	34.7	35.9	32.8	25.5	32.5	34.8
a*	-6.7	-6.4	-5.5	-5.0	-5.6	-5.6	-4.6	-6.4
b*	-15.6	-17.7	-14.9	-15.6	-17.6	-15.9	-17.9	-15.6
C	23.2	22.3	22.5	22.7	21.3	22.3	22.3	21.1
h°	253.0	245.4	246.0	267.0	249.4	252.2	250.8	253.0
K/S	12.6	12.5	12.9	13.2	12.2	11.7	12.8	13.5
(a) → Kum kum, (b) → Bar berry, (c) → Annatto, (d) → Onion, (e) → Red Sandal Wood, (f) → Grape, (g) → Madder, and (h) → Reactive dye								

3.3. FASTNESS PROPERTY VALUES OF PA AND CT TREATED DYED SILK FABRICS

The results for the wash, light, stain and rub fastness properties received from the silk fabric treated with PA and CT applications followed by the dyeing process with natural dyes such as kum kum, bar berry, annatto, onion, red sandalwood, grape, and madder and synthetic reactive dye are presented in Table 5. There is a very good overall fastness properties shown by the PA and CT treated dyed silk fabrics over that of the respective untreated silk fabrics. The maximum over all fastness properties is exhibited by the CT treated dyed silk fabrics. The PA and CT treated and dyed silk fabrics show good to very good wash fastness property values of 3-4; also, very good light fastness property values of 4-5; similarly, very good stain fastness property values of 3-4; and lastly the rubbing fastness property values [2-3] are only poor to moderate. In general, the overall good fastness properties in the PA and CT treated silk fabrics is exhibited due to the improved application and subsequently the presence of the functional groups responsible with the material.

Table 5

Table 5 Fastness Properties of PA and CT Treated Dyed Silk Fabrics

Natural Coloring Sources →		**(a)**	**(b)**	**(c)**	**(d)**	**(e)**	**(f)**	**(g)**	**(h)**
Testing Parameters		**Fastness Properties of PA Treated Dyed Silk Fabrics**							
Wash		3	3	3	3-4	3	3	3	3-4
Light		4	4	4	4-5	4	3-4	4	4-5
Stain		2-3	3	2-3	3-4	3	2-3	3	4
Rub	Wet	2-3	2	2-3	2-3	2	2-3	3	2

	Dry	3	3	3-4	3	3	3-4	3-4	3
Natural Coloring Sources →		**(a)**	**(b)**	**(c)**	**(d)**	**(e)**	**(f)**	**(g)**	**(h)**
Testing Parameters		**Fastness Properties of CT Treated Dyed Silk Fabrics**							
Wash		3	3	3-4	3-4	3	3	3-4	4
Light		4-5	4	4-5	5	4	4	4	5-6
Stain		3	3-4	3	4	3-4	3	3-4	4-5
Rub	Wet	2-3	2-3	2-3	2-3	2-3	2-3	3	2-3
	Dry	3-4	3-4	3-4	3-4	3-4	3-4	3-4	3
Natural Coloring Sources →		**(a)**	**(b)**	**(c)**	**(d)**	**(e)**	**(f)**	**(g)**	**(h)**
Testing Parameters		**Fastness Properties of Treated Dyed Silk Fabrics (NO Treatment)**							
Wash		3	2-3	3	3	3	2-3	3	3-4
Light		4	3-4	4	4	3-4	3	4	4-5
Stain		2-3	3	2-3	3-4	3	2-3	3	3-4
Rub	Wet	2	2	2	2	2	2	2	2
	Dry	2	2-3	2-3	3	2	2-3	3	2-3
(a) → Kum kum, (b) → Bar berry, (c) → Annatto, (d) → Onion, (e) → Red Sandal Wood, (f) → Grape, (g) → Madder, and (h) → Reactive dye									

3.4. THE HAND VALUES (PHV) OF THE PA AND CT TREATED DYED SILK FABRICS

The hand values such as; smoothness, stiffness, and fullness of the silk fabric treated with PA and CT followed by dyeing with natural dyes and synthetic reactive dye are shown in Table 6. It is seen from the Table 6 that there is a maximum smoothness for the CT treated dyed silk fabric followed by the PA treated and no treated silk fabrics. There is a respective around 25% and 7% increase of smoothness value for CT treated dyed silk fabrics over that of untreated and PA treated ones. There is a reasonably decrease in stiffness values (av. 7% and 10%) for PA and CT treated dyed silk fabrics over that of untreated one. There is considerably more (av. 11% and 15%) fullness values for the PA and CT treated dyed silk fabrics compared to that of untreated one. When compared between the CT and PA treated dyed silk fabrics the former one shows around 5% more values.

Table 6

Table 6 The Hand Values (PHV) of the PA and CT Treated Dyed Silk Fabrics										
Natural Coloring Sources →		**(O)**	**(a)**	**(b)**	**(c)**	**(d)**	**(e)**	**(f)**	**(g)**	**(h)**
Silk Fabric Treatment		**Hand Value of the Treated Dyed Silk Fabrics**								
PA	**Smoothness**	7.2	7.6	7.6	7.5	7.7	7.5	7.5	7.6	7.8
	Stiffness	7.0	6.8	6.9	6.8	6.7	6.8	6.9	6.8	6.6
	Fullness	7.3	7.5	7.6	7.6	7.8	7.7	7.5	7.6	7.9
CT	**Smoothness**	8.0	8.2	8.3	8.3	8.5	8.3	8.4	8.4	8.6
	Stiffness	6.7	6.6	6.6	6.5	6.4	6.6	6.6	6.5	6.4
	Fullness	7.7	7.8	7.9	7.9	8.2	8.1	8.0	7.9	8.2
NO	**Smoothness**	5.9	6.1	6.2	6.2	6.3	6.2	6.1	6.2	6.3

Stiffness	7.4	7.3	7.3	7.2	7.2	7.3	7.3	7.3	7.2
Fullness	6.5	6.6	6.7	6.6	6.8	6.6	6.7	6.7	6.9
(O) → No dye, (a) → Kum kum, (b) → Bar berry, (c) → Annatto, (d) → Onion, (e) → Red Sandal Wood, (f) → Grape, (g) → Madder, and (h) → Reactive dye									

3.5. BENDING LENGTH AND CREASE RECOVERY OF THE PA AND CT TREATED DYED SILK FABRICS

The values related to bending length and crease recovery of the PA and CT treated dyed silk fabrics are presented in the Table 7. From the Table 7, it is visible that the bending length is relatively reduced both in warp as well in weft way correspondingly as the silk fabrics are applied with PA and CT and subsequently dyed. The bending length is appreciably considered as the flexibility of the textile fabric which is regarded as the valid component responsible for many utilities. There would be more bending length in the textile fabric which comprises high stiffness, lack good drape and also the flexibility. Hence, the bending length can also be referred as the falling length when textile fabrics fall by their own weight with respect to the specific length and also the specific angle. One of the important properties of the textile materials are considered to be crease recovery by which it can return to its original shape after being creased. Consecutively, the notified quantitative measure of the crease resistance is mentioned as the crease recovery angle. In accordance with that the maximum crease recovery is shown by the CT treated dyed silk fabrics followed by the PA treated and untreated one.

Table 7

Table 7 Bending Length and Crease Recovery of the PA and CT Treated Dyed Silk Fabrics

	Natural Coloring Sources →		(O)	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
Silk Fabric Treatment	**Bending Length and Crease Recovery of the Treated Dyed Silk Fabric**										
PA	**Bending Length (mm)**	**Warp**	10.0	9.9	9.8	9.9	9.7	9.9	9.8	9.9	9.6
		Weft	9.7	9.6	9.5	9.6	9.4	9.6	9.5	9.6	9.3
	Crease Recovery (º)	**Warp**	114	112	112	112	110	111	112	111	109
		Weft	112	111	111	110	108	110	110	109	107
CT	**Bending Length (mm)**	**Warp**	9.6	9.4	9.4	9.5	9.2	9.4	9.3	9.5	9.1
		Weft	9.3	9.2	9.2	9.3	8.9	9.2	9.1	9.2	8.8
	Crease Recovery (º)	**Warp**	117	115	114	115	113	114	115	114	111
		Weft	113	110	110	111	109	110	111	110	108
NO	**Bending Length (mm)**	**Warp**	10.4	10.3	10.3	10.2	10.1	10.2	10.2	10.2	10.0
		Weft	10.2	10.1	10.1	10.0	9.9	10.1	10.1	10.1	9.8
	Crease Recovery (º)	**Warp**	111	108	109	108	107	108	109	109	106
		Weft	109	105	106	105	103	105	106	106	102
(O) → No dye, (a) → Kum kum, (b) → Bar berry, (c) → Annatto, (d) → Onion, (e) → Red Sandal Wood, (f) → Grape, (g) → Madder, and (h) → Reactive dye											

PA – Polyacrylic Treated, CT – Chitosan Treated, NO – No Treatment Silk Fabrics

3.6. ASSESSMENT OF ANTIBACTERIAL ASPECTS ON THE PA AND CT TREATED DYED SILK FABRICS

The assessment based on staphylococcus aureus and escherichia coli for antibacterial results of PA and CT treated dyed silk fabrics are given in the Table 8. Subsequently, the antimicrobial effect was assessed by the conventional qualitative method in the silk fabrics. It is seen from the table that the silk fabrics show a higher zone of inhibition against Staphylococcus aureus when compared to Escherichia coli. The CT and PA treated dyed silk fabrics show a significant increase of antibacterial activity over the untreated one of nearly 30% and 25% respectively. Subsequently the CT treated dyed silk fabrics show around 8% increase over the PA treated one. The textile products possessed with antimicrobial properties has generated a fast-improving trend setting for varied items towards the end user's mind; the clean, clear and fashioned aspects that initiated a lot for the stimulated intensive research and development.

Table 8

Table 8 Assessment of Antibacterial Aspects on the PA and CT Treated Dyed Silk Fabrics

Natural Coloring Sources →		(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
Silk Fabric Treatment		**Assessment of Antibacterial Aspects on the Treated Dyed Silk Fabrics**							
PA	**SA**	36	37	36	38	36	36	37	40
	EC	34	35	33	36	34	34	35	37
CT	**SA**	39	40	39	41	39	38	39	43
	EC	36	37	37	39	36	35	36	41
NO	**SA**	27	27	28	29	28	27	28	31
	EC	25	26	25	26	25	24	25	29

(a) → Kum kum, (b) → Bar berry, (c) → Annatto, (d) → Onion,
(e) → Red Sandal Wood, (f) → Grape, (g) → Madder, and (h) → Reactive dye

3.7. UV PROTECTION FACTOR ASSESSMENT OF THE PA AND CT TREATED DYED SILK FABRICS

The UPF – uv protection factor values for PA and CT treated dyed silk fabrics are given in the Table 9. There is a considerable improvement in the uv protection factor on the PA and CT treated dyed silk fabrics as evidenced from the Table 9. There is nearly 52% and 42% respective increase of UPF on CT and PA treated dyed fabric over that of the untreated one. Compared to the PA treated one, the CT treated silk fabric shows more than 15% increase of UPF values. Based on this improvement, it is revealed that the CT treated dyed silk fabrics are in the excellent uv protection category when compared with that of the respective PA treated (very good) and untreated ones. According to this concept, it is indicated that chitosan application is regarded as the best choice for the silk fabric to be protected from the uv rays. The quantum of protection provided to the human skin by the textile fabric from the ultraviolet rays is expressed by the scientific term UPF - ultraviolet protection factor. The UPF values are tested as per the conventional instrumental measurements whereas the Sun Protection Factor - SPF values for sunscreens are checked by human testing. The ratio of the average effective uv-irradiance studied for unprotected skin to the average uv-irradiance calculated for skin protected by the test textile fabric is known to as UPF. The measure of ultraviolet protection factor is mentioned as the amount of uv-radiation that penetrates a textile fabric and reaches the skin. Ultraviolet protection factor measures the sensitive uv-A and uv-B radiation blocked and also ultraviolet protection factor rating is directed for the material and not for the design of the textiles.

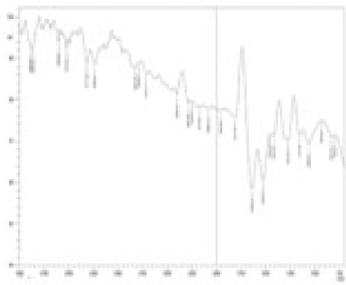
Table 9

Table 9 UV protection Factor Assessment of the PA and CT Treated Dyed Silk Fabrics								
Natural Coloring Sources →	**(a)**	**(b)**	**(c)**	**(d)**	**(e)**	**(f)**	**(g)**	**(h)**
Silk Fabric Treatment	**UV Protection Factor Assessment of the Treated Dyed Silk Fabrics**							
PA	35	36	36	38	36	35	36	39
CT	42	41	41	44	42	41	42	45
NO	20	21	20	22	20	20	21	22
Standard Ultraviolet Protection Factor Rating			**Ultraviolet Protection Factor Rating**		15 to 24	25 to 39	40 to 50	
			Effect of Protection		Good	Very Good	Excellent	
			Blocked (%) for uv Radiation		93.3 - 95.9	96 to 97.4	97.5 or more	
(a) → Kum kum, (b) → Bar berry, (c) → Annatto, (d) → Onion, (e) → Red Sandal Wood, (f) → Grape, (g) → Madder, and (h) → Reactive dye								

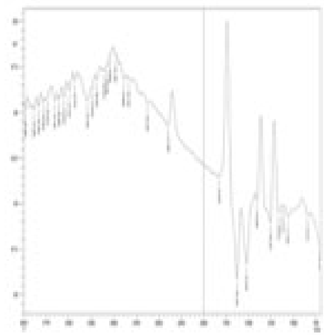
3.8. FTIR GRAPHS OF THE PA AND CT TREATED DYED SILK FABRICS

The FTIR graphs of silk fabrics; raw silk (1a), degummed silk (1b), PA and CT treated silk fabrics (1c, 1d), PT treated, and CT treated followed by bar berry dyeing (1e, 1f), PT treated, and CT treated followed by reactive dyeing (1g, 1hf) respectively are given in the Figure 1. The influence of PA and CT treatment followed by the suitable dyeing on silk fabrics are presented in this Figure. From the graphs, it is clear that when the silk fabrics are treated with PA and CT (1c, 1d) followed by dyeing with bar berry (1e, 1f) and reactive dye (1g, 1h) respectively the wavelength of the FTIR graph is differed from the no treatment silk fabric (1a, 1b) which leads for the knowledge for the effective application of PA and CT on the silk fabric. When look into these FTIR graphs it is visible that the basic polymer structure which seems to be intact without any change. Consequently, based on the subsequent increase of the PA and CT treatments and the following coloration there is a indication of small variation in the peaks in specific range of the graphs.

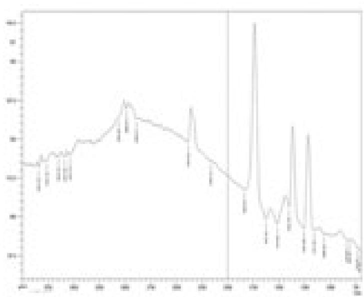
Figure 1



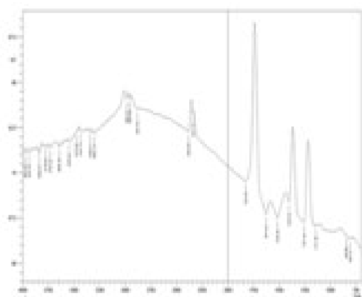
1a. Raw Silk Fabric



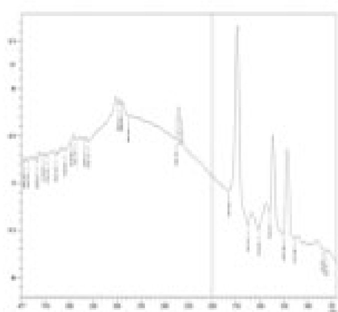
1b. Degummed Silk Fabric



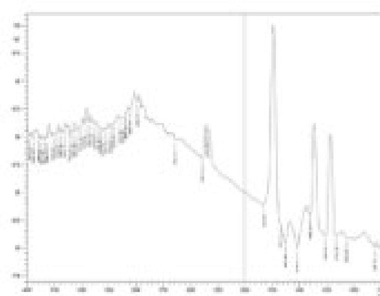
1c. PA Treated Silk Fabric



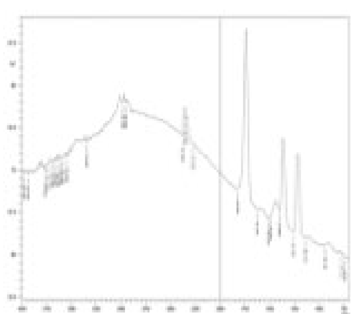
1d. CT Treated Silk Fabric



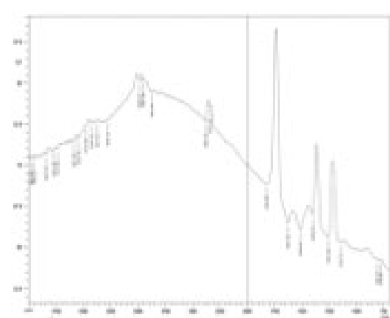
1e. PA Treated Bar berry Dyed Silk



1f. CT Treated Barberry Dyed Silk



1g. PA Treated Reactive Dyed Silk



1h. CT Treated Reactive Dyed Silk

Figure 1 FTIR Analysis of the Silk Fabric

4. CONCLUSION

It is concluded from the outcome of this research that the basic textile properties such as tensile strength & elongation, stiffness / bending modulus, drape co-efficient, and thermal resistance values of the PA treated and CT treated silk fabrics reveal very good the protection behaviour needed for the textile products. The colorimetric values shown by the PA treated and CT treated dyed silk fabrics are significantly more that is applicable for the respective end use materials. The overall fastness values of the PA and CT treated dyed silk fabrics are in the good trend acceptable for the apparel and garment products. The smoothness, stiffness and fullness hand values of the PA and CT treated dyed silk fabrics are significantly good. The bending length as well the crease recovery of PA and CT treated dyed silk fabrics in both warp as well as weft directions as required for the textiles and garments are in the good trend.

The PA treated and CT treated dyed silk fabrics show a remarkable increase of the antibacterial effect for staphylococcus aureus and escherichia coli and gave the influence of the protection aspects against the bacterial action in the silk textile fabric and garments. The uv protection behaviours of the PA treated and CT treated dyed silk fabrics are progressively in the increased trend related for the suitability of silk fabrics and garments. The FTIR graphs lead for the knowledge and confirm the activity of the PA and CT treatments and dyeing with natural dyes and synthetic reactive dye towards the silk fabrics.

CONFLICT OF INTERESTS

None.

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