Study of K/S, Anti-bacterial, UV-protection, Anti-odor and SEM on Chemical Treated Cotton Fabrics

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ABSTRACT
In this research work cotton fabrics were treated with sodium hydroxide, morpholine and cellulase enzyme. The treated fabrics were then dyed with some selected natural dyes such as annatto, onion, pomegranate, indigo, myrobalan, bar berry; and synthetic dyes such as reactive and sulphur dyes. These treated samples were tested for their dyeing characteristics (K/S value, fastness properties, washing, light, rubbing and stain resistance), anti-bacterial, uv-protection, anti-odor behaviors and SEM study. Among the treated fabrics, sodium hydroxide treated cotton fabric exhibited the best properties.

Keywords: Cotton fabrics, K/S, anti-bacterial, uv-protection, anti-odor, SEM

INTRODUCTION

Cotton is the most widely used textile fiber in the world. World textile fiber consumption at the end of 20th century was approximately 45 million tons. India holds the largest area under cotton cultivation and ranked third in world's cotton production and is the second largest consumer of cotton [1, 2]. Unlike synthetic fibers, cotton is a natural product [3] and is non-allergic. The use of natural dyes has increased recently in production and in its usage by human beings due higher awareness of harmful effects of chemical dyes [4, 5, 6]. The use of many different natural dyes can be traced ancient times [7-10].

Cotton has a high absorbency rate [11] and holds up to 27 times its own weight in water. Cotton swells in a high humidity environment, in water and in concentrated solutions of certain acids, salts and bases [12, 13]. However, the moist cotton can be easily attacked by bacteria. Antimicrobial textiles with improved functionality have a variety of applications in health and hygiene products, especially the garments worn close to the skin [14-21]. With increasing world population and the spread of disease, the number of antibiotic resistant microorganisms is rising along with the occurrence of infections from these microorganisms. To address these growing concerns in the environment, researches are focused on the use of reusable textiles with durable finishes [7]. The importance of antimicrobial textiles goes hand-in-hand with the rise in resistant strains of microorganisms [8, 22]. In this study cotton (woven and knitted) fabrics were treated with sodium hydroxide, morpholine, and cellulase enzyme followed by dyeing and finishing in an attempt to improve bacterial resistance dyeing characteristics, uv-protection and odor resistance.. In textile dyeing, reactive and sulphur dyes are widely used because of their high fastness properties. However, the use of natural sources is increasing due to their coloration and functional properties. Hence, some selected natural sources and synthetic dyes (reactive and sulphur) were applied to the cotton fabrics with the aforementioned chemical treatments. The fabrics tested for their dyeing characteristics (K/S value, fastness properties-washing, light, rubbing and stain resistance), anti-bacterial, uv-protection, anti-odor behaviors and characterized using scanning electron microscopy (SEM).

MATERIALS AND METHODS

Materials

Cotton (woven and knitted) fabrics with following specifications were used in this study:

Woven (plain) Fabric					Knitted fabric		
Ends / Inch	Picks / Inch	GSM	Yarn Count		Yarn count (Ne)	GSM	Loop length (mm)
			Warp	Weft			
84	94	146.1	27.1	26.1	27.5	136.9	2.6

Commercially available natural dyes [annatto (*bixa orellana*), onion (*allium cepa*), pomegranate (*punica granatum*), indigo (*indigofera tinctoria*), myrobalan (*terminalia chebula*), bar berry (*berberis vulgaris*)] and synthetic dyes [reactive dye (reactive red HB – C.I. No. Red 24), and sulphur dye (sulphur black – C.I. No. sulphur Black 1)] used. The chemicals mentioned elsewhere in this study were AR grade.

Methods

Treatment on Cotton (Woven and Knitted) Fabrics

The cotton fabrics (woven and knitted) were pretreated (scouring and bleaching) per established techniques (Shukla, 2000; Trotman, 1984). The pretreated cotton fabrics (woven and knitted) were treated with a) sodium hydroxide of the concentration 15% (owm) for one hour at 85°C; b) aqueous solution of morpholine 40% for one hour at 40°C; and c) cellulase enzyme of the concentration 4.0% (owm) for one hour at 70°C.

Dyeing & K/S Analysis of Cotton (Woven and Knitted) Fabrics

The dyeability of cotton fabrics (woven and knitted) was investigated using natural and synthetic dyes. Dyeing was carried out at boil for two hours with a material to liquor ratio of 1:20 as per the established technique for natural and synthetic dyes. The dyed samples were washed, soaped and dried [23, 24]. The K/S values ('K' and 'S' indicate the absorption coefficient and scattering coefficient respectively of the colorant that predict the behavior of the dyes on the textile materials) of natural and synthetic dyed cotton fabrics were determined by AATCC Test Method [25] using a Datacolor SF 600 plus spectrophotometer interfaced to a PC. Measurements were taken of color presence, brightness, dullness and color intensity with the specular component of the light excluded and the UV component included using illuminant D65 and 10° standard observer. Each fabric was folded once so as to give two thicknesses and an average of five readings is reported.

Color Fastness Analysis of the Cotton (Woven and Knitted) Fabrics

The natural and synthetic dyed samples were washed under condition IIIA of AATCC Test Method 124-2001 to determine the color change [26]. Light fastness tests were carried out according to AATCC Test Method 16 E-1998 [27]. The samples were exposed to 5, 10 AFUs (AATCC Fading Unit) to determine the color change AATCC 16-1998 [28]. AATCC standardized crock meter was used to determine the rubbing fastness of naturally dyed fabrics under wet and dry condition to assess the color change and staining properties AATCC 61-1996 [29].

Antimicrobial Assessment of the Cotton (Woven and Knitted) Fabrics

The antibacterial activity on the natural dyed (annatto, onion, pomegranate, indigo, myrobalan and bar berry) and synthetic dyed (reactive dye and sulphur dye) cotton (woven and knitted) fabrics was assessed qualitatively according to the AATCC test method 147-2004 by the parallel streak method [30].

UV Protection Finishing on Cotton (Woven and Knitted) Fabrics

A UV protective finish Super FX Anti UV was applied to the cotton fabrics using a concentration of 5 gpl, 80°C, 60 minutes. The finished fabrics were then tested using standard methods [31, 32].

Organoleptic Evaluation of Control on Cotton Fabrics - After 48 hrs (In House Method)

The treated and dyed cotton fabrics (woven and knitted) were finished with anti-odor agent H9000 at a concentration of 5 gpl, at 75°C, 45 minutes. Then they were evaluated by six judges. The judges made anti-odor evaluations [33, 34] 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 ("no odor") to 0 ("very intense and disagreeable odor").

SEM Study on Dyed and Finished Cotton (Woven and Knitted) Fabrics

Scanning electron microscope studies were carried out on dyed and finished woven and knitted cotton fabrics using a 30kV scanning electron microscope JEOL (Japan) Model JSM-6360 [35].

RESULTS AND DISCUSSION

K/S Values of Dyed Cotton (Woven and Knitted) Fabrics

The K/S values of the fabrics are given in *Table I*. From this table it is observed that woven cotton fabric shows higher K/S values than the knitted cotton fabric. The K/S value of sodium hydroxide treated cotton fabric is higher than those of morpholine treated, cellulase treated and untreated cotton fabrics [36]. The K/S value of the sodium hydroxide treated cotton fabric is influenced by the higher swelling action of that solution compared to that of morpholine or cellulase. Among the dyes applied to the pre-treated cotton fabrics there are only marginal differences in the K/S values; however, reactive dye shows highest K/S value. The color characteristics of dyed surfaces depend on how the surface reflects incident light. This in turn depends on the specific scattering of a given surface and the color characteristics of the dyestuff [37, 38]. Even though the pre-treated woven knitted cotton fabrics possess only small differences in K/S values as a function of type of dye used, the values obtained for the woven fabrics are generally higher than those of the corresponding knitted fabrics.

TABLE I. K/S Values of Dyed Cotton (Woven and Knitted) Fabrics.

S. No.	Dyes	Colors Obtained	K/S Values of the Dyed Cotton Fabric							
			Woven				Knitted			
			1	2	3	4	1	2	3	4
1	Annatto	Orange	12.47	13.98	13.1	12.88	12.08	13.72	12.77	12.63
2	Onion	Orange Red	12.51	14.5	13.17	13.15	12.25	13.7	12.98	12.88
3	Pomogranate	Brown	12.64	14.47	13.52	13.35	12.18	13.76	12.84	12.7
4	Indigo	Blue	13.24	14.6	14.33	14.3	12.98	14.01	13.45	13.15
5	Myrobalan	Green	12.48	14.45	13.62	13.48	12.65	13.66	13.76	12.81
6	Bar berry	Yellow	12.75	14.54	13.41	13.4	12.65	13.95	13.32	13.02
7	Reactive Dye	Red	13.95	15.07	14.95	14.92	13.62	14.42	14.25	14.05
8	Sulphur Dye	Black	13.6	14.65	14.32	14.3	13.32	14.21	13.65	13.35

1. Untreated cotton
2. Sodium hydroxide treated cotton
3. Morpholine treated cotton
4. Cellulase enzyme treated cotton

Washing Fastness of the Dyed Cotton (Woven and Knitted) Fabrics

The washing fastness of the dyed woven and knitted cotton fabrics are given in *Table II*. It is evident from this table that there is no significant improvement in the wash fastness of the woven and knitted cotton fabric (sodium hydroxide treated, morpholine treated, cellulase treated and untreated) dyed with annatto, onion, pomogranate, indigo, myrobalan, bar berry, reactive dye, and sulphur dyes. However, the sodium hydroxide treated and dyed cotton fabric shows improved wash fastness [36] compared to the corresponding morpholine treated, cellulase treated and untreated cotton fabrics. Among the dyes applied to the cotton fabrics the reactive dyed one has highest wash fastness. The woven fabrics show a marginal increase in wash fastness over the knitted dyed fabrics.

TABLE II. Washing fastness of the Dyed Cotton (Woven and Knitted) Fabrics.

S.No.	Dyes	Washing Fastness of the Dyed Fabric							
		Woven				Knitted			
		1	2	3	4	1	2	3	4
1	Annatto	3	3-4	3-4	3	3	3-4	3	3
2	Onion	3	4	3-4	3-4	2-3	3-4	3-4	3
3	Pomogranate	0.3	3-4	3	3	0.3	3	3	3
4	Indigo	3-4	4-5	4	4	3-4	4	4	4
5	Myrobalan	3	3-4	3-4	3-4	2-3	3-4	3-4	3
6	Bar berry	3	3-4	3	3	3	3	3-4	3-4
7	Reactive Dye	3-4	4-5	4-5	4	3-4	4-5	4	4
8	Sulphur Dye	3-4	4-5	4	4	3-4	4	4	4

1. Untreated cotton
2. Sodium hydroxide treated cotton
3. Morpholine treated cotton
4. Cellulase enzyme treated cotton

Light Fastness of the Dyed Cotton (Woven and Knitted) Fabrics

The light fastness data for the dyed woven and knitted cotton fabrics is presented in *Table III*. From this table, it is seen that the overall the light fastness of the fabrics is good (average 4-5). The sodium hydroxide treated cotton fabric shows higher light fastness values than the morpholine treated; cellulase treated and untreated cotton fabrics [36]. The higher light fastness of the sodium hydroxide treated fabrics is a result of the higher swelling and resultant higher uptake of the fabrics during the dyeing process. Among the specific types of dye, the reactive dye shows the highest light fastness value. The woven fabrics show higher light fastness values than the corresponding knitted fabrics.

TABLE III. Light fastness of the Dyed Cotton (Woven and Knitted) Fabrics.

S.No.	Dyes	Light Fastness of the Dyed Cotton Fabric							
		Woven				Knitted			
		1	2	3	4	1	2	3	4
1	Annatto	4	5	4-5	4-5	3-4	4-5	4	4
2	Onion	4	5	5	4-5	3-4	4-5	4	4
3	Pomogranate	4	5	5	4	3-4	4-5	4-5	4
4	Indigo	4-5	5-6	5-6	5-6	4	5	5	4-5
5	Myrobalan	4	5-6	5	4-5	3-4	5	5	4-5
6	Bar berry	3-4	4-5	4-5	4	3-4	4-5	4	4
7	Reactive Dye	4-5	6	6	5-6	4	5-6	5-6	5
8	Sulphur Dye	5	6	5-6	5-6	4	5-6	5	5

1. Untreated cotton
2. Sodium hydroxide treated cotton
3. Morpholine treated cotton
4. Cellulase enzyme treated cotton

Rubbing Fastness of the Dyed Cotton (Woven and Knitted) Fabrics

The rubbing fastness of the fabric samples in the wet and dry state are given in *Table IV*. *Table IV* shows that the rubbing fastness in the dry state is much higher than in the wet state. The reactive dyes show marginal high value of rubbing fastness than the other dyes in both the wet and dry state. The sodium hydroxide treated cotton fabrics show increased rubbing fastness [36] values compared to those of the cellulase and untreated fabrics. The sodium hydroxide treatment increases the swelling and thus the dye penetration into the fabric, resulting in increased rubbing fastness. The average rubbing fastness values of the woven cotton fabrics are higher than those of the corresponding knitted fabrics.

TABLE IV. Rubbing fastness of the Dyed Cotton (Woven and Knitted) Fabrics.

S. No.	Dyes	Rubbing Fastness of the Dyed Cotton Fabric															
		Woven								Knitted							
		1		2		3		4		1		2		3		4	
		Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
1	Annatto	2	2	2-3	4	2-3	3-4	2-3	3	2	2	2-3	3-4	2-3	3-4	2	3
2	Onion	2	2-3	2-3	4	2-3	3-4	2	3	2	2-3	2-3	3-4	2	3	2	3
3	Pomogranate	2	2-3	2-3	3-4	2-3	3-4	2-3	3-4	1-2	2-3	2-3	3-4	2-3	3	2	3
4	Indigo	2	3	3	3-4	2-3	3-4	2	3	1-2	2-3	2-3	3	2	3	2	3
5	Myrobalan	2	2	2-3	3-4	2-3	3-4	2	3	1-2	2	2-3	3-4	2	3-4	2	3
6	Bar berry	2	2-3	2-3	4	2-3	3-4	2-3	3-4	2	2-3	2-3	4	2-3	4	2-3	4
7	Reactive Dye	2	3	3	4	3	3-4	3	3-4	2	2-3	2-3	4	2-3	4	2-3	4
8	Sulphur Dye	2	2-3	2-3	3-4	2-3	3	2	3	1-2	v	2-3	3	2	3	2	3

1. Untreated cotton
2. Sodium hydroxide treated cotton
3 .Morpholine treated cotton
4. Cellulase enzyme treated cotton

Stain Resistance of the Dyed Cotton (Woven and Knitted) Fabrics

The stain resistance of the dyed woven and knitted cotton fabrics is compared in *Table V*. From this table, it is seen that the stain resistance of synthetic dyes is marginally higher than that of the natural dyes for all fabric samples. The sodium hydroxide treated cotton fabrics (woven and knitted) show higher stain resistance values than morpholine treated, cellulase treated and untreated fabrics [36]. The woven fabrics show marginally higher stain resistance values over the corresponding knitted fabrics.

TABLE V. Stain Resistance of the Dyed Cotton (Woven and Knitted) Fabrics.

S. No.	Dyes	Stain Resistance of the Dyed Cotton Fabrics							
		Woven				Knitted			
		1	2	3	4	1	2	3	4
1	Annatto	3	4	3-4	3-4	2-3	3-4	3-4	3
2	Onion	2-3	4	3	3	2-3	3-4	3	3
3	Pomogranate	3	4	3-4	3-4	2-3	3-4	3	3
4	Indigo	3	4-5	4	3-4	3	4	3-4	3
5	Myrobalan	3-4	5	4	4	3	4	3-4	3-4
6	Bar berry	3	4	3-4	3-4	3	3-4	3-4	3
7	Reactive Dye	3-4	5	4	4	3-4	4	4	4
8	Sulphur Dye	3-4	4-5	4	4	3	4	3-4	3-4

1. Untreated cotton
2. Sodium hydroxide treated cotton
3 .Morpholine treated cotton
4. Cellulase enzyme treated cotton

Antibacterial Assessment of the Dyed Cotton (Woven and Knitted) Fabrics

The antimicrobial assessment of the fabric samples is given in *Table VI*. The antimicrobial activity of these samples was assessed by a qualitative test method. All dyed samples showed a higher zone of inhibition against Staphylococcus aureus compared to Escherichia coli. In general, the sodium hydroxide treated cotton fabric [36] (woven and knitted) shows a higher zone of inhibition (both by Staphylococcus aureus and Escherichia coli) followed by morpholine treated, cellulase treated and untreated cotton fabrics. The reactive dye shows higher inhibition than the sulphur dye among synthetic dyes. Indigo dye shows the highest inhibition of all the natural dyes.

TABLE VI. Anti-bacterial Assessment of the Dyed Cotton (Woven and Knitted) Fabrics.

S. No.	Dyes	Anti-bacterial Activity of the Natural and Synthetic Dyed Cotton (Woven and Knitted) Fabrics															
		Woven Fabric								Knitted Fabric							
		1		2		3		4		1		2		3		4	
		SA	EC	SA	EC	SA	EC	SA	EC	SA	EC	SA	EC	SA	EC	SA	EC
1	Annatto	26	25	33	31	29	27	27	26	24	22	34	28	28	27	27	25
2	Onion	27	26	33	30	29	28	27	27	25	23	32	28	28	26	26	25
3	Pomogranate	27	25	34	31	30	28	28	26	25	22	33	28	29	27	28	26
4	Indigo	31	29	37	35	34	31	33	30	29	26	35	34	33	30	31	29
5	Myrobalan	27	26	33	31	30	29	28	27	25	24	32	29	29	28	27	26
6	Bar berry	29	28	35	32	32	30	30	29	26	24	33	30	30	29	28	26
7	Reactive Dye	37	35	45	43	41	38	39	36	34	32	43	40	40	36	38	32
8	Sulphur Dye	33	31	39	38	37	35	35	32	31	29	38	37	36	33	34	30

SA → Staphylococcus aureus EC → Escherichia coli
1. Untreated cotton
2. Sodium hydroxide treated cotton
3. Morpholine treated cotton
4. Cellulase enzyme treated cotton

UV Protection Factor for the Dyed & Finished Cotton Fabrics

The UV transmittance of the finished cotton fabrics was determined using a UV visible spectrophotometer. The standard chart for determining the UV protection factor is presented in the *Table VII*, and the data of UV protection factors of the finished cotton fabrics are given in *Table VII(a)*. The UV protection factor (UPF) values of all dyed and finished fabrics fall between 33 and 40. The sodium hydroxide treated fabrics have the highest UV protection factors (38-40). The untreated cotton fabrics show the lowest UPF values (33-35). From *Tables VII*, the UPF's of the dyed and finished samples fall between 94 and 97 percent.

TABLE VII. Standard Chart for UPF Rating for the Fabrics.

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 VII(a). UV Protection factor for the dyed (natural and synthetic) & finished woven and knitted cotton fabrics.

S. No.	Dyes	UPF rating of the dyed (natural and synthetic) & finished woven and knitted cotton fabrics							
		Woven Cotton Fabric				Knitted Cotton Fabric			
		1	2	3	4	1	2	3	4
1	Annatto	34	39	38	37	35	40	39	38
2	Onion	33	38	37	36	36	39	38	38
3	Pomogranate	34	38	37	36	33	39	37	36
4	Indigo	33	38	37	36	34	39	38	37
5	Myrobalan	35	39	38	37	35	40	39	38
6	Bar berry	34	39	37	36	34	39	37	36
7	Reactive Dye	33	39	37	36	34	40	38	37
8	Sulphur Dye	35	39	38	37	36	40	39	38

1. Untreated cotton
2. Sodium hydroxide treated cotton
3 .Morpholine treated cotton
4. Cellulase enzyme treated cotton

Anti-Odor Behavior of the Treated, Dyed and Finished Cotton Fabrics

The anti-odor behavior of the fabrics is given in *Table VIII and VIII(a)*. These fabrics were assessed using a subjective evaluation technique performed by six women of different age categories (25 to 50 years) and the odor grading was rated between 0 repulsive) and 10 (ideal). The odor ratings of all fabrics fall in the range of 7-9 (good to excellent). No distinct trends in anti-odor rating among the various types of dye or pre-treatments are evident.

TABLE VIII. Anti-odor behavior of the treated, dyed and finished woven cotton fabrics (assessed by Women).

S. No.	Dyes	Anti odor behavior of the dyed (natural and synthetic) & finished woven cotton fabrics																							
		1						2						3						4					
		A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F
1	Annatto	8	8	7	8	8	7	9	8	9	9	9	8	8	8	8	8	9	8	8	8	8	8	9	8
2	Onion	8	7	7	8	7	8	9	8	8	9	8	9	9	8	8	9	8	9	9	8	8	9	8	9
3	Pomogranate	8	7	7	7	8	7	9	8	8	8	9	8	8	7	8	8	9	7	8	7	8	7	8	8
4	Indigo	7	8	8	7	7	8	9	8	8	9	8	9	8	8	7	9	8	9	7	8	8	9	7	8
5	Myro balan	9	7	7	8	8	7	8	9	8	8	9	8	8	8	8	8	8	8	8	8	7	8	8	8
6	Bar berry	7	8	8	7	8	7	9	9	8	9	9	9	8	7	8	9	9	8	8	8	8	9	9	7
7	Reactive Dye	8	7	8	8	7	8	9	8	9	9	9	8	9	7	9	9	8	8	9	7	9	9	8	8
8	Sulphur Dye	8	8	7	7	8	7	9	9	8	9	9	9	8	8	8	9	8	8	8	8	8	8	8	8

1. Untreated cotton
2. Sodium hydroxide treated cotton
3. Morpholine treated cotton
4. Cellulase enzyme treated cotton

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 – 7 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

TABLE VIII(a). Anti-odor behavior of the treated, dyed and finished knitted cotton fabrics (assessed by Women).

S. No.	Dyes	Anti odor behavior of the dyed (natural and synthetic) & finished woven cotton fabrics																							
		1						2						3						4					
		A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F
1	Annatto	7	8	7	8	8	7	9	8	9	9	9	8	8	8	8	8	9	8	8	8	8	8	9	8
2	Onion	8	7	8	8	7	8	9	8	8	9	8	9	9	8	8	9	8	9	9	8	8	9	8	9
3	Pomogranate	8	7	7	7	8	7	9	8	8	8	9	8	8	7	8	8	9	7	8	7	8	8	9	8
4	Indigo	7	8	8	8	7	8	9	8	8	9	8	9	8	8	8	9	8	9	7	8	8	9	7	8
5	Myro balan	8	7	7	8	8	7	8	9	8	8	9	8	8	8	8	8	8	8	8	8	7	8	8	8
6	Bar berry	7	8	8	8	8	7	9	9	8	9	9	9	8	8	8	9	9	8	8	8	8	9	9	7
7	Reactive Dye	8	7	8	8	7	8	9	8	9	9	9	8	9	7	9	9	8	8	9	7	9	9	8	8
8	Sulphur Dye	7	8	7	7	8	7	9	9	8	9	9	9	8	9	8	9	8	8	8	8	8	8	8	8

1. Untreated cotton
2. Sodium hydroxide treated cotton
3. Morpholine treated cotton
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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 – 7 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 Behavior and Release Rate of the Dyed and Finished Cotton Fabrics

The concentration of the anti-odor agent was measured by a UV / visible spectrophotometer after extracting the anti-odor agent from the finished fabric sample using ethanol. The extracted material was diluted to a 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 IX* (woven cotton fabric) and *Table IX(a)* (knitted cotton fabric) respectively. From theses tables it is seen that the anti-odor retention behavior is very good even after 4 and 8 days. The release rate of anti-odor agent from the fabrics is increases from about 8% after 4 days to nearly 20% after 8 days in both types of cotton fabrics. All the dyed fabrics gave uniformly good anti-odor retention behavior based on the data in *Tables IX and IX(a).*

TABLE IX. Anti-odor retention behavior and release rate of the dyed (natural and synthetic) and finished woven cotton fabrics.

S. No.	Dyes	Retention of anti-odor agent on the fabrics (mg/g)												Release rate of anti-odor agent from the fabrics (%)							
		1			2			3			4			1		2		3		4	
		A	B	C	A	B	C	A	B	C	A	B	C	X	Y	X	Y	X	Y	X	Y
1	Annatto	324	295	258	340	315	278	339	312	276	338	310	272	8.3 .7	19.8	8.0 .7	18.7	7.8 .7	19.2	8.1 .7	19.4
2	Onion	321	292	255	340	311	272	336	309	272	335	307	268	8.5	19.9	7.7	18.9	8.1	19.3	8.3	19.5
3	Pomogranate	322	294	259	342	315	280	338	312	278	338	309	276	8.4	20	7.6	19	8	19.4	8.2	19.6
4	Indigo	323	296	262	342	316	282	339	314	280	337	312	277	8.5	19.9	7.7	18.9	8.1	19.3	8.3	19.7
5	Myro balan	320	290	252	338	310	272	336	306	268	334	305	268	8.5	19.9	7.6	18.7	8	19	8.3	19.3
6	Bar berry	321	292	255	339	312	275	338	310	272	336	307	269	8.4	19.9	7.5	18.7	7.9	19.1	8.2	19.4
7	Reactive Dye	324	298	262	342	316	281	340	315	279	339	312	277	8.6	19.6	7.7	18.4	8.1	18.8	8.3	19.1
8	Sulphur Dye	323	300	264	345	318	285	342	316	282	340	315	278	8.5	19.7	7.6	18.5	8	18.9	8.4	19.2

1. Untreated cotton
2. Sodium hydroxide treated cotton
3. Morpholine treated cotton
4. Cellulase enzyme treated cotton

Retention of Anti odor: A → Immediately B → After 4 Days C → After 8 Days
Release Rate of Anti odor: X → After 4 Days Y → After 8 Days

TABLE IX(a). Anti-odor retention behavior and release rate of the dyed (natural and synthetic) and finished knitted cotton fabrics.

S. No.	Dyes	Retention of anti-odor agent on the fabrics (mg/g)												Release rate of anti-odor agent from the fabrics (%)							
		1			2			3			4			1		2		3		4	
		A	B	C	A	B	C	A	B	C	A	B	C	X	Y	X	Y	X	Y	X	Y
1	Annatto	326	298	262	344	318	282	342	315	279	340	313	276	8.1 .7	19.5	7.3 .7	18.4	7.6 .7	18.8	7.8 .7	19.1
2	Onion	323	295	258	343	314	276	340	312	274	338	310	272	8.3	19.6	7.4	18.6	7.8	19	8	19.2
3	Pomogranate	325	297	262	345	318	284	342	316	281	341	313	279	8.2	19.7	7.3	18.7	7.7	19.1	7.9	19.3
4	Indigo	326	300	265	345	320	285	343	317	283	340	315	280	8.3	19.7	7.4	18.7	7.8	19	8	19.3
5	Myro balan	323	293	256	341	313	275	339	310	272	337	308	271	8.3	19.5	7.3	18.3	7.7	18.7	8	19
6	Bar berry	323	296	258	343	315	278	341	313	276	339	310	273	8.1	19.6	7.2	18.4	7.6	18.8	7.8	19.1
7	Reactive Dye	327	302	265	346	320	285	344	318	283	342	316	280	8.3	19.3	7.4	18	7.8	18.5	8	18.8
8	Sulphur Dye	326	303	267	348	322	288	345	320	285	342	318	282	8.2	19.4	7.3	18.2	7.7	18.6	7.9	18.9

1. Untreated cotton
2. Sodium hydroxide treated cotton
3. Morpholine treated cotton
4. Cellulase enzyme treated cotton

Retention of Anti odor: A → Immediately B → After 4 Days C → After 8 Days
Release Rate of Anti odor: X → After 4 Days Y → After 8 Days

SEM Analysis of Woven Cotton Fabric

The SEM images of indigo dyed and finished woven cotton fabrics (untreated, sodium hydroxide treated, morpholine treated and enzyme treated) are given in the *Figures 1(a), 1(b), 1(c), and 1(d)* respectively. It is evident from these images that there are some clear differences in the respective images The dyed and finished sodium hydroxide treated cotton fabric (*Figure 1(b)*) shows much lower levels of fiber damage than the morpholine treated (*Figure 1(c)*) and enzyme treated (*Figure 1(d)*) fabrics [36].

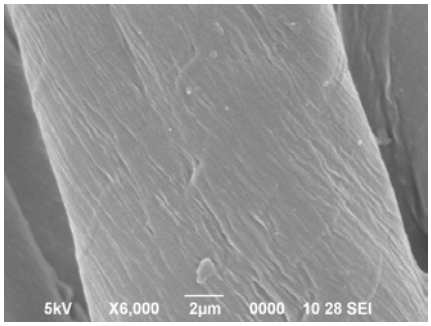

FIGURE 1(a). Untreated, dyed/finished.

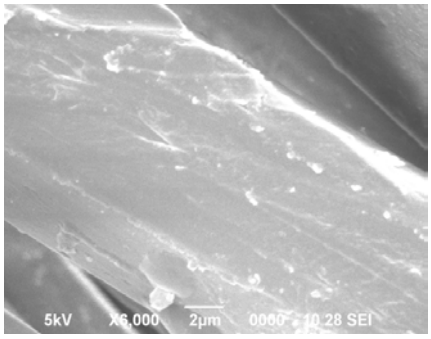

FIGURE 1(b). NaOH treated, dyed/finished.

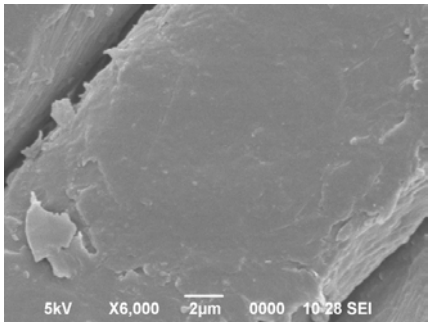

FIGURE 1(c) Morpholine treated, dyed/finished.

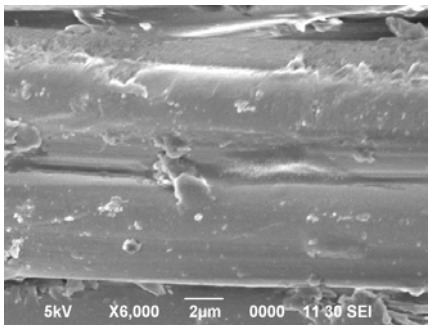

FIGURE 1(d). Enzyme treated, dyed/finished.

SEM Analysis of Knitted Cotton Fabric

The SEM images of dyed and finished knitted cotton fabrics (untreated, sodium hydroxide treated, morpholine treated and enzyme treated) are given in the *Figures 2(a), 2(b), 2(c), and 2(d)* respectively. It is evident that there are some clear differences in the respective images. The dyed and finished sodium hydroxide treated cotton fabric (*Figure 2(b)*) shows much lower levels of fiber damage than the morpholine treated (*Figure 2c)*) and enzyme treated (*Figure 2(d)*) fabrics.

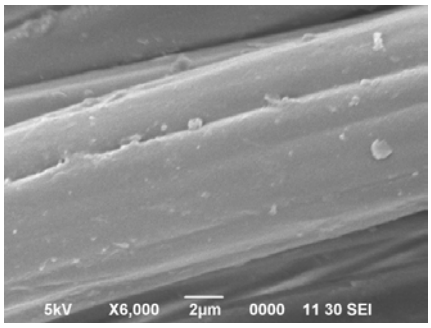

FIGURE 2(a). Untreated, dyed/finished.

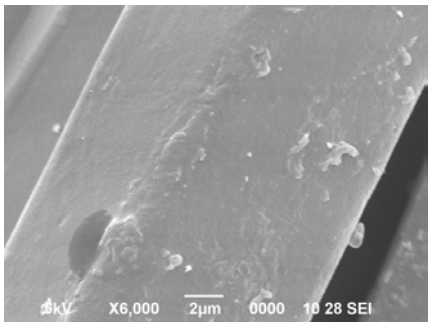

FIGURE 2(b). NaOH treated, dyed/finished.

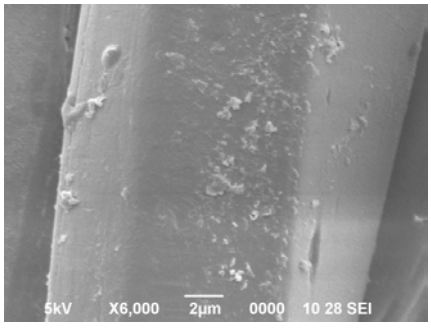

FIGURE 2(c). Morpholine treated, dyed/finished**.**

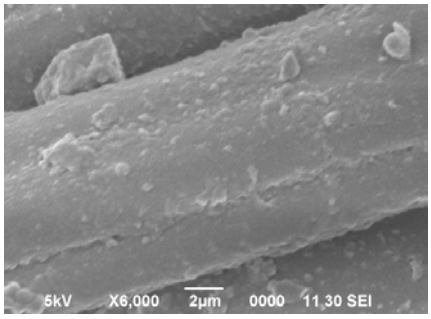

FIGURE 2(d). Enzyme treated, dyed/finished

CONCLUSION

From this research work on cotton (woven and knitted) fabrics (sodium hydroxide treated, morpholine treated, cellulase treated and untreated) dyed with annatto, onion, pomogranate, indigo, myrobalan, barberry, reactive dye and sulphur dyes, the following conclusions are possible: The sodium hydroxide treated cotton fabrics give the best color data followed by morpholine treated and cellulase enzyme treated cotton fabrics. In general, the overall fastness properties are highest for the sodium hydroxide treated cotton fabrics followed by morpholine treated and cellulase enzyme treated cotton fabrics. All dyed samples showed a higher zone of inhibition against Staphylococcus aureus compared to Escherichia coli. In general, the sodium hydroxide treated cotton fabric (woven and knitted) shows a higher zone of inhibition (both by Staphylococcus aureus and Escherichia coli) followed by morpholine treated, cellulase enzyme treated cotton fabrics. All dyed and finished cotton exhibit very good UV resistance. The anti-odor behavior of the cotton fabrics is excellent to very good. The anti-odor retention behavior of these fabrics is also very good.

SEM micrographs reveal that the dyed and finished sodium hydroxide treated cotton fabrics are closet to the untreated fabrics in appearance followed by morpholine treated and enzyme treated fabrics.

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REFERENCES

[1] Shaw, H.L., *Symposium on* "Cotton's Importance in the Textile Industry", Lima, Peru, 1998.

[2] Simpson, V., "India's Textile and apparel industry: Growth Potential and Trade and Investment Opportunities", Staff Research Study, Office of Industries, U. S. International Trade Commission, Washington, 2011.

[3] Duckett, K.E., "Surface Properties of Cotton Fibers, Surface Characteristics of Fibers and Textiles" Fiber Science Series, Marcel Dekker Inc., New York, 1975.

[4] Kloos, W.E., Musselwhite, M.S., "Distribution and persistence of Staphylococcusaureus and Micrococcus species and other aerobic bacteria on human skin", *Appl Microbiol.* 30(3), 1975, 381–395.

[5] Vigo, T.L., Leonas, K.K., "Antimicrobial activity of fabrics containing crosslinked polyethylene Glycols", *Text Chem Color*., 1(9), 1984, 42-46.

[6] Chung, Y.S., Kuen, K., Kim, J. W., "Durable press and antimicrobial finishing of cotton fabrics with a citric acid and chitosan treatment", *Text Res J*. 68(10), 1982, 772-775.

[7] Jothi, D., "Experimental Study on Antimicrobial Activity of Cotton Fabric Treated With Aloe Gel Extract From Aloe Vera Plant for Controlling the Staphylococcusaureus (bacterium)", *African Journal of Microbiological Research*, 3(5), 2009, 228-232.

[8] Chengaiah, B., Rao, K. M., Kumar, K. M., Alagusundaram, M., Chetty, C. M., "Medicinal importance of natural dyes – a review", *International Journal of Pharm Tech Research*, 2 (1), 2010, 144-154.

[9] Anna Hartl, Christian R. Vogl, "The Potential Use of Organically Grown Dye Plants in Organic Textile Industry", *Journal of sustainable Agriculture*, 23(2), 2003, 17.

[10] Ramachandran, T., Rajendrakumar, K., Rajendran, R., "Antimicrobial Textiles – An Overview", *IE (I) Journal – TX*, 84, 2004, 42-47.

[11] Meenaxi Tiwari, Archana Singh., Alka Ali., "Resist printing on cotton fabric with vat dye using different resisting agents", *Asian Dyer* 2009, 32 - 35.

[12] Brandrup, J., Immergut, E.H., "Polymer Handbook", John Wiley, New York, 1989.

[13] Lewin, M., "Handbook of Fiber Chemistry", 3rd edition, CRC Press, Baco Raton,USA, 2007.

[14] Payne, J.D., Kudner, D.W., "A new durable antimicrobial finish for cotton textiles", *Am Dyest Rep*. 28(5), 1996, 26–30.

[15] Morris, C.E., Welch, C.M., "Use of aluminum or titanium compounds to bind antimicrobial agents to cotton fabrics", *Text Res J*. 53(3), 1983, 143–147.

[16] Morris, C. E., Vigo, T. L., Welch, C.M., "Binding of Organic Antimicrobial Agents to Cotton Fabrics as Zirconium Complexes", *Text Res J*, 51(2), 1981, 90–96.

[17] Anon., "A pressing need for a new wrinkle: DP finishing of garment dyed product", *AATCC*, 19(12), 1987, 32–36.

[18] Menezes, E., "Antimicrobial finishing for specialty textiles", *Clothesline*. 5, 2002, 96–99.

[19] Sun, G., Xu, X., "Durable and regenerable antibacterial finishing of fabrics: Biocidal properties", *Text Chem Color*. 30(6), 1981, 26–30.

[20] Sekar, N., "Antimicrobial finishes on cotton developments", *Colourage*, 12, 2001, 37–38.

[21] Bhattacharya, S.D., Shah, S.R., Aliquzzaman, M.D., "Improved processing procedures in garment manufacturing", *Am Dyest Rep*. 39(5), 1995, 34–37.

[22] Bonin, L. E., "Durable and reusable antimicrobial textiles", *M. Sc. In the school of human ecology Thesis*, Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College, 2008.

[23] Trotman, E.R., "Dyeing and Chemical Technology of Textile Fibers", 6th edition, Edward Arnold, London, 1984.

[24] Mohanty, B.C., Chandramauti, K.V., Naik, H. D., " Natural Dyeing Process of India", Published by Calico Museum of Textiles, India, 1987.

[25] AATCC Test Method 135-1985, "Colour measurement of textiles", Instrumental Technical manual of the AATCC, Research Triangle Path, USA, 2003.

[26] AATCC Test method 61, 2(A)- 2001, "Odor fastness to laundering, Home and Commercial", Technical manual of the AATCC, Research Triangle Park, U.S.A, 2001.

[27] AATCC Test Method 16-1998, "Colour fastness to light", Technical Manual of the AATCC, Research Triangle Park, USA, 2003.

[28] AATCC Test Method 61-1996, "Colour fastness to laundering: Home and Communication - accelerated", Technical manual of the AATCC, Research. Triangle Park, U.S.A, 2003.

[29] AATCC test method 8-2007, "Colour fastness to crocking", Technical Manual of the AATCC, Research Triangle Park, U.S.A, 2007.

[30] AATCC Test Method 147, "Antibacterial Activity Assessment of Textile Materials– Parallel Streak Method", Technical Manual of the AATCC, Research Triangle Park, USA. 2004.

[31] Bajaj, P., "Ecofriendly Finishes for Textiles", *Indian Journal for Fiber and Textile Research*, 26(1), 2001, 162-186.

[32] Thilagavathi, G., Krishna Bala, S., Kannaian, T., "Microencapsulation of Herbal Extracts for Microbial Resistance in Healthcare Textiles", *Indian Journal Fibre Text Res*, 32, 2007, 351.
[33] Anjalikarolia, Snehal Mendapara, "Imparting Antimicrobial and Fragrance Finish on Cotton Using Chitosan with Silicon Softener", *Indian Journal of Fibre & Textile Research*, 32, 2007, 99.
[34] Thilagavathi, G., Kannaian., "Combined Antimicrobial and Aroma Finishing Treatment for Cotton, using Microencapsulated Geranium (Pelargonium Graveolens L' Herit. ex. Ait.) Leaves Extract", *Indian Journal of Natural Products and Resources*, 1 (3), 2010, 348-352.
[35] Gouda, M., Hebeish, A., "Preparation and Evaluation of CuO/Chitosan Nanocomposite for Antibacterial Finishing Cotton Fabric", *Journal of Industrial Textiles*, 39 (3), 2010, 203 – 213.
[36] Tamane Wagaw, Chavan, R.B., "Optimization of Caustic Soda Concentration for Causticization of Cotton", *Scientific Reports*, 1(9), 2012, 1-6.
[37] Mourad, S., Emmel, P., Simon, K., "Extending Kubelka-Munk′s Theory with Lateral Light Scattering", International Conference on Digital Printing Technologies, Florida, USA, 2001.
[38] Wyszecki, G., Stiles, W.S., Color Science (Concept and Methods, Quantitative Data and Formulae), John Wiley & Sons, INC., ISBN 0- 471-02106-7, USA, 2000.

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