

# STUDY OF THE CHEMICAL TREATMENT ON COTTON FABRICS TO INCREASE THE UV PROTECTION AND ANTI-ODOUR RETENTION PROPERTIES

## PAMUKLU KUMAŞLARIN UV KORUMA VE KALICI KOKU ÖNLEME ÖZELLİKLERİNİ ARTIRMAK İÇİN KİMYASAL İŞLEMLERİN İNCELENMESİ

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### ABSTRACT

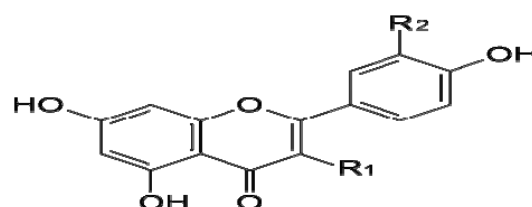
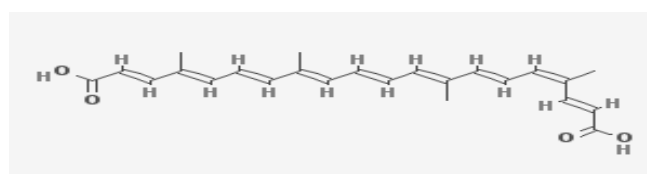
There is a heavy demand for cotton materials in diversified areas, and the research works on them are increased tremendously in the recent days. Chemical treatment of cotton cellulose without changing their fibrous form is a common practice in the textile industry. In this paper, cotton (woven and knitted) fabrics are selected and reacted with sodium hydroxide, morpholine or cellulase enzyme. The fabrics are then dyed by 6 different natural dyes: annatto, onion, pomegranate, indigo, myrobalan, barberry; and 2 synthetic dyes (reactive and sulphur dyes) and subsequently finished. The fabrics are then studied for their dyeing characteristics (K/S value), antibacterial activities, anti-odour and UV protection behaviour.

**Keywords:** Cotton fabrics, NaOH, morpholine, and cellulase enzyme, anti-odour, UV protection

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### 1. INTRODUCTION

Among all the textile fibers cotton is the most widely used one in the world. In the end of 20<sup>th</sup> century, world textile fiber consumption was approximately 45 million tons; and cotton represented approximately 20 million tons of them [1]. India holds the largest area of 8 m ha under cotton cultivation and ranked third in world's cotton production, next to China & USA and second largest consumer of cotton [1, 2]. Unlike synthetic fibers, cotton is a natural product [3] and non-allergic since it doesn't irritate sensitive skin or cause allergies [4, 5]. Nowadays, the use of natural dyes has increased due to the improvement in environmental concern, with increased awareness about harmful effects of chemical dyes both in production and in its usage by human beings [6, 7 & 8]. This dye has the rare distinction of being a dye whose use can be traced back to antiquity and which continues to be as commonly used all over the world today, since they contain the required chromophore and auxochrome required for the dye properties as seen in the following structure for the representative natural dyes annatto and barberry respectively [9,10 11, 12 & 13].



Cotton has a high absorbency rate and holds up to 27 times its own weight in water [14, 15]. 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, and also have several medical applications in infection control and barrier material [16 – 24]. With increase in world population and the spread of disease, the

number of antibiotic resistant microorganisms is rising along with the occurrence of infections from these microorganisms [25, 26]. To address these growing concerns in the environment, researches are focused on the use of reusable textiles with durable finishes [9]. The importance of antimicrobial textiles goes hand-in-hand with the rise in resistant strains of microorganisms [10, 27]. There is a need for the study on cotton textiles to improve its behaviour with some chemical treatments. Hence, in this study cotton (woven and knitted) fabrics were given treatment with sodium hydroxide, morpholine, and cellulase enzyme followed by dyeing and finishing so as to increase its behaviour further. The fabrics were dyed with both synthetic and natural type of dyes, since natural dyes are being considered very important for natural cotton textile materials. The fabrics tested for their dyeing characteristics (K/S value), antibacterial activities, anti-odour and UV protection behaviour after dyeing with some selected dyes such as annatto, onion, pomegranate, indigo, myrobalan, barberry (natural dyes); and reactive and sulphur dyes (synthetic) respectively revealed very good results.

## 2. EXPERIMENTAL

### 2.1 Materials

The specification of cotton (woven and knitted) fabrics used in this study are given in the following Table (1).

Natural dyes [annatto (bixa orellana), onion (allium cepa), pomegranate (punica granatum), indigo (indigofera tinctoria), myrobalan (terminalia chebula), barberry (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 were in the commercial grade (Forest Department, Coimbatore, India). The commercial Super FX UltraSoft 2015 (Tirupur, India) was used for finishing on cotton fabrics. The other chemicals mentioned elsewhere for this study were in analytical grade (AR) grade.

### 2.2 Methods

#### 2.2.1 Pretreatment on cotton (woven and knitted) fabrics

The cotton fabrics (woven and knitted) were pretreated (scouring and bleaching) with 3% (owm – on weight of material) sodium hydroxide at boil for three hours (for scouring) followed by treatment with 1% (owm) hydrogen peroxide at boil for two hours (for bleaching) as per the established technique [28, 29].

#### 2.2.2 Sodium hydroxide treatment on cotton (woven and knitted) fabrics

The cotton fabrics (woven and knitted) were treated with sodium hydroxide of the concentration 15% (owm) for one hour at 85°C.

#### 2.2.3 Morpholine treatment on cotton (woven and knitted) fabrics

The cotton fabrics (woven and knitted) were treated with aqueous solution of morpholine 40% for one hour at 40°C.

#### 2.2.4 Cellulase enzyme treatment on cotton (woven and knitted) fabrics

The cotton fabrics (woven and knitted) were treated with Cellulase enzyme of the concentration 4.0% (owm) for one hour at 70°C.

#### 2.2.5 Dyeing 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 with the concentration of 2% (owm) for synthetic dyes and 25 gpl (gram per litre) for natural dyes 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 [29, 30].

#### 2.2.6 Silicone softener finishing on cotton (woven and knitted) fabrics

The fabrics were finished with silicone softener (Super FX UltraSoft 2015) (Dosage: 5 – 10 gpl, pH: 5 – 7, 30°C, 70 – 80% pick up, padded and dried at room temperature) and tested accordingly [31, 32].

#### 2.2.7 Antimicrobial assessment of the cotton (woven and knitted) fabrics

The antibacterial activity on the natural dyed (annatto, onion, pomegranate, indigo, myrobalan and barberry) and synthetic dyed (reactive dye and sulphur dye) cotton (woven and knitted) fabrics was assessed [33] qualitatively according to the AATCC test method 147-2004 by the parallel streak method.

#### 2.2.8 Organoleptic evaluation of odour control on cotton fabrics - after 48 hrs (In house method)

The treated and dyed cotton fabrics (woven and knitted) were finished with anti-odour finishing agent H9000 of the concentration 5 gpl, at 75°C, 45 minutes. Then they were evaluated by six judges. The judges made anti-odour evaluations [34, 35], 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 odour grading scale was 10 to 0 (“no odour” to “very intense and disagreeable odour”).

Table 1. Specifications of cotton fabrics

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

## 2.2.9 UV protection finishing on cotton (woven and knitted) fabrics

The UV protection finishing was given to the cotton fabrics using Super FX Anti UV with concentration 5 gpl, 80°C, 60 minutes. The finished fabrics were then tested according to the standard method [33, 34, 36].

## 3.0 Results and Discussion

### 3.1 K/S values of dyed cotton (woven and knitted) fabrics

The K/S values of the dyes such as annatto, onion, pomogranate, indigo, myrobalan, barberry, reactive dye (H), and sulphur dye applied on cotton (woven and knitted) fabrics (sodium hydroxide treated, morpholine treated, cellulase treated and untreated) are given in Table 1. From this table it is observed that woven cotton fabric shows overall high K/S values than the knitted cotton fabric. The K/S values of sodium hydroxide treated cotton fabric are maximum when compared with morpholine treated, cellulase treated and untreated cotton fabrics. The higher K/S values on the sodium hydroxide treated cotton fabric are influenced by the higher swelling action of sodium hydroxide followed by morpholine treatment and cellulase treatment [13, 25 & 36]. Among the dyes applied on the cotton fabric (sodium hydroxide treated, morpholine treated, cellulase treated and untreated) there is only a marginal differences in the K/S values; however reactive dye shows the maximum K/S values. Even though the woven cotton fabric and knitted cotton fabric posses only a small differences in the K/S values for the dyes (annatto, onion, pomogranate, indigo, myrobalan, barberry, reactive dye (H), and sulphur dye) applied on the cotton fabrics (sodium hydroxide treated, morpholine treated, cellulase treated and untreated); there is a uniform trend maintained in these values and the values of woven fabric give an edge over the knitted fabric.

### 3.2 Antibacterial assessment of the dyed cotton (woven and knitted) fabrics

The antimicrobial assessment of the dyed (annatto, onion, pomogranate, indigo, myrobalan, barberry, reactive dye,

and sulphur dye) woven and knitted cotton fabrics (sodium hydroxide treated, morpholine treated, cellulase treated and untreated) is given in Table 2. The antimicrobial activity of these samples was assessed by qualitative test method. All these dyed samples showed a higher zone of inhibition against *Staphylococcus aureus* when compared to *Escherichia coli* [26, 34, & 35]. In general, the sodium hydroxide treated cotton fabric (woven and knitted) shows a higher zone of inhibition (both by *Staphylococcus aureus* and *Escherichia coli*) which is around 20% more than that of untreated, 8% more than that of morpholine treated and 15% more than that of cellulase treated cotton fabrics (woven and knitted) when dyed with annatto, onion, pomogranate, indigo, myrobalan, barberry, reactive dye (H), and sulphur dye. The reactive dye shows maximum inhibition followed by sulphur dye in synthetic dye category whereas indigo gives maximum inhibition followed by other natural dyes when dyed on cotton fabrics (woven and knitted) fabrics (sodium hydroxide treated, morpholine treated, cellulase treated and untreated) as exhibited by *Staphylococcus aureus* and *Escherichia coli*.

### 3.3 Anti-odour behaviour of the treated, dyed and finished cotton fabrics

The anti-odour behaviour of the dyed (annatto, onion, pomogranate, indigo, myrobalan, barberry, reactive dye, and sulphur dye) woven and knitted cotton fabrics (sodium hydroxide treated, morpholine treated, cellulase treated and untreated) is given in Table 3 and 3(a) respectively. These fabrics were assessed by subjective evaluation technique performed by six women of different age categories (25 to 50 years) and the odour 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-odour assessment performed show that the average anti-odour behaviour of cotton fabrics is around 8 which is a very good value [34, 35].

Table 1. K/S values of dyed cotton (woven and knitted) fabrics

S. No.	Dyes	Colours 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	13.10	12.88	12.08	13.72	12.77	12.63
2	Onion	Orange Red	12.51	14.50	13.17	13.15	12.25	13.70	12.98	12.88
3	Pomogranate	Brown	12.64	14.47	13.52	13.35	12.18	13.76	12.84	12.70
4	Indigo	Blue	13.24	14.60	14.33	14.30	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	Barberry	Yellow	12.75	14.54	13.41	13.40	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	13.60	14.65	14.32	14.30	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

**Table 2.** Antibacterial assessment of the dyed cotton (woven and knitted) fabrics

S. No.	Dyes	Antibacterial activity of the natural and synthetic dyed cotton (woven and knitted) fabrics – Qualitative method [zone of inhibition, mm]															
		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	Barberry	29	28	35	32	32	30	30	29	26	24	33	30	30	29	28	26
7	Reactive Dye ((H) (H))	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

**Table 3.** Anti-odour behaviour of the treated, dyed and finished woven cotton fabrics (assessed by Women)

S. No.	Dyes	Anti-odour behaviour 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	8	7	8	8
6	Barberry	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 3(a).** Anti-odour behaviour of the treated, dyed and finished knitted cotton fabrics (assessed by Women)

S. No.	Dyes	Anti-odour behaviour of the dyed (natural and synthetic) & finished knitted 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	8	9	8	9	8	8	8	9	8	9	7	8	8	9	7
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	Barberry	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
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

### 3.4 Anti-odour retention behaviour and release rate of the dyed and finished cotton fabrics

The concentration of the anti-odour agent was measured by UV / visible spectrophotometer by extracting the anti-odour 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 4 (woven cotton fabric) and Table 4 (a) (knitted cotton fabric) respectively. From these tables it is noticed that the anti-odour retention behaviour is very good even after its test in 4 days and 8 days. The release rate of anti-odour agent from the fabrics is subsequently increased from the average of nearly 8% for 4 days to nearly 20% for 8 days in both the type of cotton fabrics. All the dyed fabrics give uniformly good anti-odour retention behaviour [34, 35] as evidenced in the Tables 4 and 4(a).

**Table 4.** Anti-odour retention behaviour and release rate of the dyed (natural and synthetic) and finished woven cotton fabrics

S. No.	Dyes	Retention of anti-odour agent on the fabrics (mg/g)												Release rate of anti-odour 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	20.0	7.6	19.0	8.0	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	8.0	19.0	8.3	19.3
6	Barberry	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	8.0	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-odour : A → Immediately ; B → After 4 Days ; C → After 8 Days

Release Rate of Anti-odour : X → After 4 Days ; Y → After 8 Days

**Table 4 (a).** Anti-odour retention behaviour and release rate of the dyed (natural and synthetic) and finished knitted cotton fabrics

S. No.	Dyes	Retention of anti-odour agent on the fabrics (mg/g)												Release rate of anti-odour 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	19.0	8.0	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	19.0	8.0	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	8.0	19.0
6	Barberry	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	18.0	7.8	18.5	8.0	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-odour : A → Immediately ; B → After 4 Days ; C → After 8 Days

Release Rate of Anti-odour : X → After 4 Days ; Y → After 8 Days

### 3.5 UV protection factor for the dyed & finished cotton fabrics

The UV transmittance of the treated, dyed and finished cotton fabrics (woven and knitted) were determined using UV visible spectrophotometer. The standard chart for determining the UV protection factor is presented in the Table 5, and the data of UV protection factor for these fabrics are given in Table 5(a).

#### 3.5.1 Standard chart for UPF rating for the fabric

The UV transmittance of the finished cotton fabrics were determined using UV visible spectrophotometer. The standard chart for determining the UV protection factor is presented in the table 5, and the data of UV protection factor for the finished cotton fabrics (woven and knitted) are given in table 5(a).



**Table 5.** 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

### 3.5.2 UV protection factor for the dyed and finished cotton fabrics

The UV protection factor (UPF) for the cotton fabrics is given in Table 5 (a). The UPF values of all the dyed and finished fabrics are between 33 and 40 respectively. The maximum UPF value (average 38) is given by the treated [sodium hydroxide (39), morpholine (38) and cellulase (37)] cotton fabrics dyed with natural dyes and synthetic dyes; whereas the minimum UPF value (average 34) is seen for untreated cotton fabric dyed by natural dyes and synthetic dyes. From these data (Tables 5 & 5(a)) it is clear that there is a very good UV protection category as revealed by UPF rating (33 – 39) for the dyed and finished cotton fabrics [25, 26]. Similarly, the untreated cotton fabric also shows the UPF rating of average 34 which is also in the very good (UPF) category, however, the increase of UPF value is more than 10% after these treatments. Therefore based on this, the increase of the percent UV radiation blockage by these fabrics (dyed and finished cotton fabrics) would be highly appreciable for the garments and apparels [25, 26, 34, & 35].

### 4. Conclusion

From this research work the following conclusions are arrived;

The K/S values of the dyes such as annatto, onion, pomogranate, indigo, myrobalan, barberry, reactive dye, and sulphur dye applied on cotton (woven and knitted) fabrics (sodium hydroxide treated, morpholine treated, cellulase treated and untreated) are good. The sodium hydroxide treated cotton fabrics show maximum colour data followed by morpholine treated and cellulase enzyme treated cotton fabrics.

The antimicrobial character of the dyed (annatto, onion, pomogranate, indigo, myrobalan, barberry, reactive dye, and sulphur dye) woven and knitted cotton fabrics (sodium hydroxide treated, morpholine treated, cellulase treated and untreated) is good. All these dyed samples showed a higher zone of inhibition against *Staphylococcus aureus* when 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.

The anti-odour behaviour of cotton fabrics is excellent to very good. Similarly the anti-odour retention behaviour of these fabrics is also very good. There is a very good increase of UV protection category for the dyed and finished cotton fabrics.

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**Table 5 (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	Barberry	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

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