Study of Mechanical and Surface Properties on Some Chemical Treated Cotton Fabric By KES-F, SEM and FTIR Analysis

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***ABSTRACT* - Chemical treatment of cotton cellulose to alter its properties of the fibers without changing their fibrous form is a common practice nowadays in the textile industry. In this paper cotton (woven and knitted) fabrics are selected and reacted with sodium hydroxide, morpholine, and cellulase enzyme. The fabrics are then dyed by some selected dyes such as annatto, onion, pomegranate, indigo, myrobalan, bar berry (natural dyes); and reactive and sulphur dyes (synthetic) respectively and subsequently finished. These fabrics are then analyzed for mechanical and surface properties from KES-F, and assessed by SEM and FTIR.**

Keywords : Cotton fabrics, Chemical treatment, KES-F, SEM and FTIR
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1. INTRODUCTION

Today cotton is the most used textile fiber in the world. World textile fiber consumption in the end of 20th century was approximately 45 million tons. Of this total, cotton represented approximately 20 million tons (Lawrence, 1998). 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 (Lawrence, 1998 and Simpson, 2011).

Unlike synthetic fibres, cotton is a natural product (Duckett, 1975) and non-allergic since it doesn't irritate sensitive skin or cause allergies. Cotton has a high absorbency (Meenaxi et al, 2009) rate 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 (Brandrup and immergut, 1989). Chemical treatment of cotton cellulose to alter physical properties of the fibers without changing their fibrous form is a common practice in the textile industry (Lewin, 2007).

In the application of dyestuffs to cotton, several factors are considered as of prime importance (Morris et al, 1981; Menezes, 2002; and Sun & Xu, 1981). The importance of natural dyes has increased presently, with increased awareness about harmful effects of chemical dyes both in production and in its usage by human beings (Kloos & Musselwhite, 1975; Vigo & Leonas, 1984; and Chung et al, 1982). 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 as it is in the ancient times (Jothi, 2009; Chengaiahet al, 2010; Anna Hartl, 2003; and Ramachandran et al, 2004).

This research work focuses on the treatment of cotton (woven and knitted) fabrics with sodium hydroxide, morpholine, and cellulase enzyme in order to improve its behaviour revealed by dyeing and finishing. The cotton fabrics (treated and untreated) were dyed by some selected dyes such as annatto, onion, pomegranate, indigo, myrobalan, bar berry (natural dyes); and reactive and sulphur dyes (synthetic) respectively and subsequently finished. These fabrics were then assessed for mechanical and surface properties from KES-F, SEM analysis and FTIR studies.

2. EXPERIMENTAL

2.1. MATERIALS

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

Woven Fabric					Knitted fabric		
Ends / Inch	Picks / Inch	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

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 were in the commercial grade. 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 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) as per the established technique (Shukla, 2000; and Trotman, 1984).

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^{o}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^{o}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^{o}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 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 (Trotman, 1984; and Mohanty et al, 1987).

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^{o}C, 70 – 80% pick up, padded and dried at room temperature) and tested accordingly (Ryan, 1971; and Talebpour & Holme, 2006).

2.2.7 Objective assessment on dyed and finished cotton (woven and knitted) fabrics by KES-F

The mechanical and surface properties of the dyed and finished woven and knitted cotton fabrics were assessed by Kawabata evaluation system (KES-F) (Kawabata S, and Niwa M, 1989).

2.2.8 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 from 30kV scanning electron microscope JEOL (Japan) Model JSM-6360 (Gouda, and Hebeish,2010).

2.2.9 FTIR analysis for dyed and finished cotton (woven and knitted) fabrics

Fourier Transfer Infra Red (FTIR) spectrophotometer (Shimadzu, Japan) was used to analyze the functional groups. The data reveal about the colour absorption properties of the organic dye molecules with respect to the functional groups, aromatic and achromatic ring chains and indicated the presence of structural groups in the dye molecules (John Coates, 2000).

3.0 RESULTS AND DISCUSSION

3.1 Mechanical and surface properties from KES-F

The mechanical and surface properties of the dyed and finished cotton fabrics (woven and knitted) were objectively assessed by Kawabata evaluation system (KES-F). The primary hand value (PHV) (of both woven and knitted fabrics), bending length (of only woven fabric) fabrics, and crease recovery (of only woven fabric) of the dyed and finished cotton fabrics were carried out by this system and data are presented in Tables 1a & 1b, Table 2 and Table 3 respectively.

3.1.1 Primary hand value (PHV) of dyed and finished cotton (woven and knitted) fabrics

The parameters evaluated from KES-F of dyed and finished cotton fabrics for the primary hand value in terms of smoothness, stiffness and fullness of woven and knitted fabrics are given in Tables 1a & 1b respectively. From these Tables (1a and 1b) it is seen that the smoothness is observed more on the dyed and finished sodium hydroxide treated [2] cotton fabric followed by morpholine treated [3], enzyme treated [4] and untreated [1] cotton fabrics respectively. The undyed / unfinished untreated [UT] cotton fabrics show very low smoothness values compared to the above mentioned treated fabrics. The dyed fabrics [F1 / 1,2,3,4] when finished [F2] with the finishing agent - Super FX UltraSoft 2015, the smoothness is considerably increased in all these cases [1,2,3,4]. The increased smoothness values on the dyed and finished cotton fabrics [F1, F2 / 1,2,3,4] compared to the untreated unfinished cotton fabrics [UT] are due to the good application of dyeing and finishing as promoted by good treatments [2,3,4]. Among the dyes, the differences in smoothness values on the cotton fabrics [UT, F1, F2 / 1,2,3,4] are only marginal. Tables 1a and 1b also reveal that the stiffness of the fabrics is reduced due to the sodium hydroxide treatment, morphology treatment and enzyme treatment followed by dyeing and finishing. Compared to all treated [F1, F2 / 2,3,4] and untreated [UT, and F1, F2 / 1] fabrics the sodium hydroxide treated cotton fabrics show reduced stiffness, this is due to the good flexibility generated by sodium hydroxide; followed by morpholine treatment, enzyme treatment and untreated dyed and finished cotton fabrics. The fullness is maximum on the sodium hydroxide treated cotton fabrics followed by morpholine treated, enzyme treated and untreated fabrics. In general, the primary hand value is maximum for the sodium hydroxide treated [2] fabrics followed by morpholine treated [3], enzyme treated [4] and untreated [UT, 1] dyed [F1] and finished [F2] woven and knitted cotton fabrics (Table 1a and 1b).

TABLE 1a. PRIMARY HAND VALUE (PHV) OF DYED AND FINISHED WOVEN COTTON FABRIC

S.No.	Dyes	PHV of woven cotton fabric								
			1		*2*		*3*		*4*	
		UT	***F1***	***F2***	***F1***	***F2***	***F1***	***F2***	***F1***	***F2***
	Smoothness :									
1	Undyed	2.7	5.0	5.4	7.3	7.8	6.6	6.7	6.4	6.5
2	Annatto	2.9	5.4	5.8	7.5	7.9	6.7	6.8	6.5	6.6
3	Onion	2.8	5.3	5.5	7.4	7.6	6.6	6.7	6.5	6.6
4	Pomogranate	2.8	5.3	5.5	7.6	7.7	6.8	7.0	6.6	6.7
5	Indigo	2.7	5.2	5.5	7.4	7.6	6.7	6.8	6.5	6.7
6	Myrobalan	2.8	5.2	5.5	7.6	7.7	6.8	6.9	6.5	6.6
7	Bar berry	2.8	5.3	5.6	7.7	7.9	6.9	7.1	6.7	6.8
8	Reactive Dye	3.2	5.7	6.0	7.7	7.8	6.8	7.0	6.6	6.7
9	Sulphur Dye	2.3	4.9	5.3	7.5	7.6	6.6	6.8	6.4	6.5
	Stiffness :									
1	Undyed	5.0	4.9	4.6	4.6	4.3	4.7	4.4	4.8	4.5
2	Annatto	4.8	4.8	4.5	4.5	4.2	4.6	4.3	4.7	4.4
3	Onion	4.7	4.8	4.5	4.5	4.2	4.6	4.3	4.7	4.4
4	Pomogranate	4.8	4.8	4.5	4.5	4.2	4.6	4.3	4.7	4.4
5	Indigo	4.8	4.9	4.6	4.6	4.4	4.7	4.5	4.8	4.5
6	Myrobalan	4.5	4.8	4.5	4.5	4.2	4.6	4.3	4.7	4.4
7	Bar berry	4.8	4.8	4.5	4.5	4.2	4.6	4.3	4.7	4.4
8	Reactive Dye	4.7	4.6	4.2	4.3	3.9	4.4	4.0	4.5	4.1
9	Sulphur Dye	4.9	4.9	4.6	4.6	43	4.7	4.4	4.8	4.5
	Fullness :									

1	Undyed	4.8	7.7	8.2	9.4	9.7	8.3	8.5	8.1	8.4
2	Annatto	4.9	8.3	8.7	9.9	10.7	9.2	9.5	9.0	9.4
3	Onion	4.9	8.3	8.5	9.6	10.6	9.1	9.4	8.9	9.3
4	Pomogranate	4.8	8.1	8.5	9.5	10.4	9.0	9.4	8.8	9.3
5	Indigo	4.8	8.2	8.5	9.5	10.5	9.0	9.3	8.8	9.2
6	Myrobalan	4.8	8.3	8.4	9.4	10.4	9.0	9.4	8.8	9.3
7	Bar berry	4.9	8.3	8.6	9.5	10.5	9.1	9.4	8.9	9.3
8	Reactive Dye	5.0	8.5	8.8	9.9	10.8	9.2	9.5	9.0	9.4
9	Sulphur Dye	4.8	8.2	8.5	9.6	10.4	9.0	9.4	8.8	9.3

UT → undyed / unfinished / untreated cotton 1. Untreated cotton 2. Sodium hydroxide treated cotton
3. Morpholine treated cotton 4. Cellulase enzyme treated cotton

TABLE 1b. PRIMARY HAND VALUE (PHV) OF DYED AND FINISHED KNITTED COTTON FABRIC

S.No.	Dyed Samples	PHV of knitted cotton fabric								
			1		*2*		*3*		*4*	
		UT	*F1*	*F2*	*F1*	*F2*	*F1*	*F2*	*F1*	*F2*
	Smoothness :									
1	Undyed	2.4	4.8	5.2	6.8	7.1	6.2	6.3	5.9	6.2
2	Annatto	2.8	5.2	5.6	7.1	7.3	6.6	6.7	6.2	6.4
3	Onion	2.7	5.1	5.4	6.9	7.2	6.5	6.7	6.2	6.5
4	Pomogranate	2.6	4.9	5.3	6.7	7.2	6.3	6.6	6.0	6.3
5	Indigo	2.7	5.0	5.4	6.6	7.3	6.4	6.6	6.1	6.4
6	Myrobalan	2.6	4.9	5.3	6.6	7.3	6.3	6.5	6.0	6.3
7	Bar berry	2.8	5.1	5.5	6.7	7.4	6.4	6.5	6.2	6.4
8	Reactive Dye	3.1	5.5	5.9	7.0	7.5	6.6	6.7	6.4	6.6
9	Sulphur Dye	2.5	4.8	5.3	6.9	7.2	6.3	6.4	5.9	6.3
	Stiffness :									
1	Undyed	4.8	4.7	4.5	4.4	4.2	4.5	4.3	4.6	4.4
2	Annatto	4.7	4.6	4.4	4.3	4.1	4.4	4.2	4.5	4.3
3	Onion	4.6	4.7	4.4	4.4	4.2	4.5	4.3	4.6	4.3
4	Pomogranate	4.7	4.8	4.4	4.5	4.1	4.6	4.2	4.7	4.3
5	Indigo	4.7	4.8	4.5	4.5	4.2	4.6	4.3	4.7	4.4
6	Myrobalan	4.6	4.7	4.5	4.4	4.2	4.5	4.3	4.6	4.4
7	Bar berry	4.6	4.7	4.4	4.4	4.1	4.5	4.2	4.6	4.3
8	Reactive Dye	4.6	4.5	4.1	4.2	3.8	4.3	3.9	4.4	4.0
9	Sulphur Dye	4.8	4.8	4.5	4.5	4.2	4.6	4.3	4.7	4.4
	Fullness :									
1	Undyed	4.6	7.4	7.9	8.4	8.7	7.9	8.3	7.7	8.1
2	Annatto	4.7	8.1	8.6	8.9	9.4	8.7	9.0	8.4	8.8

3	Onion	4.9	8.1	8.5	8.8	9.3	8.6	9.0	8.4	8.7
4	Pomogranate	4.8	8.1	8.4	8.9	9.3	8.7	8.9	8.4	8.6
5	Indigo	4.8	8.0	8.4	8.8	9.2	8.6	8.8	8.3	8.6
6	Myrobalan	4.9	8.0	8.5	8.9	9.3	8.6	8.9	8.3	8.7
7	Bar berry	4.8	8.1	8.5	8.9	9.4	8.7	8.9	8.4	8.7
8	Reactive Dye	4.9	8.4	8.7	9.0	9.5	8.9	9.0	8.7	8.8
9	Sulphur Dye	4.7	8.1	8.4	8.9	9.2	8.6	8.8	8.4	8.6

UT → undyed / unfinished / untreated cotton 1. Untreated cotton 2. Sodium hydroxide treated cotton
3. Morpholine treated cotton 4. Cellulase enzyme treated cotton

3.2 Bending length of dyed and finished woven cotton fabric

The values of the bending length of untreated [UT, 1] and treated [sodium hydroxide, morpholine and enzyme] dyed and finished woven cotton fabrics are given in Table 2. From this table it is given as the data of the bending length both in warp and weft directions respectively of cotton fabric treated with sodium hydroxide, morpholine and enzyme followed by dyeing and finishing. It is evident from the Table 2 that bending length both in warp and weft directions of dyed [F1] and finished [F2] cotton fabric treated with sodium hydroxide [2] is least followed by morpholine treated [3], enzyme treated [4] and untreated [1] cotton fabrics respectively. The undyed / unfinished untreated [UT] cotton fabric shows the maximum bending length (warp and weft) which is periodically reduced after the treatments such as enzyme, morpholine and sodium hydroxide and subsequent dyeing and finishing. These treatments reduce the bending lengths on the cotton fabrics and sodium hydroxide treatment tops the list in this reduction followed by morpholine and enzyme treatments. Dyeing and finishing also further enhances the reduction in bending lengths on all these fabrics. There is no much influences in the differences of bending length due to the change of dyes (Annatto, Onion, Pomogranate, Indigo, Myrobalan, Bar berry, Reactive Dye and Sulphur dye). The warp directions have marginally more bending length values in all these woven cotton fabrics.

S.No.	Dyes	Bending length (mm) of woven cotton fabric Warp (Cw)								
		UT	*1*		*2*		*3*		*4*	
			F1	*F2*	*F1*	*F2*	*F1*	*F2*	*F1*	*F2*
1	Undyed	10.8	9.6	9.4	9.0	8.8	9.2	9.0	9.4	9.2
2	Annatto	10.3	9.5	9.3	8.9	8.6	9.1	8.8	9.3	9.0
3	Onion	10.4	9.4	9.3	8.8	8.7	9.0	8.9	9.2	9.1
4	Pomogranate	10.3	9.5	9.2	8.9	8.6	9.1	8.8	9.3	9.0
5	Indigo	10.4	9.5	9.3	8.9	8.7	9.1	8.9	9.3	9.1
6	Myrobalan	10.4	9.4	9.3	8.8	8.7	9.0	8.9	9.2	9.1
7	Bar berry	10.3	9.4	9.4	8.8	8.7	9.0	8.9	9.2	9.1
8	Reactive Dye	10.4	9.3	9.2	8.7	8.6	8.9	8.8	9.1	9.0
9	Sulphur Dye	10.4	9.2	9.3	8.6	8.5	8.8	8.7	9.0	8.9
		Bending length (mm) of woven cotton fabric Weft (Cf)								
		UT	*1*		*2*		*3*		*4*	
			F1	*F2*	*F1*	*F2*	*F1*	*F2*	*F1*	*F2*
1	Undyed	10.6	9.4	9.2	8.8	8.6	9.0	8.8	9.2	9.0
2	Annatto	10.2	9.3	9.1	8.7	8.5	8.9	8.7	9.1	8.9
3	Onion	10.2	9.2	9.1	8.6	8.5	8.8	8.7	9.0	8.9
4	Pomogranate	10.2	9.3	9.1	8.7	8.5	8.9	8.7	9.1	8.9
5	Indigo	10.2	9.3	9.2	8.7	8.6	8.9	8.8	9.1	9.0
6	Myrobalan	10.2	9.3	9.1	8.7	8.5	8.9	8.7	9.1	8.9
7	Bar berry	10.1	9.2	9.1	8.6	8.5	8.8	8.7	9.0	8.9
8	Reactive Dye	10.1	9.1	9.0	8.5	8.3	8.7	8.6	8.9	8.8
9	Sulphur Dye	10.3	9.1	9.2	8.5	8.4	8.7	8.7	8.9	9.0

Table 2. BENDING LENGTH OF DYED AND FINISHED WOVEN COTTON FABRIC

UT → undyed / unfinished / untreated cotton 1. Untreated cotton 2. Sodium hydroxide treated cotton
3. Morpholine treated cotton 4. Cellulase enzyme treated cotton

3.3 Crease recovery (°) of dyed and finished woven cotton fabric

The data of the crease recovery both in warp and weft directions of dyed and finished woven cotton fabric treated with sodium hydroxide, morpholine and enzyme are given in Table 3. From this table, it is clearly seen that the crease recovery both in warp and weft directions of dyed [F1] and finished [F2] cotton fabric treated with sodium hydroxide [2] is minimum compared to morpholine treated [3], enzyme treated [4] and untreated cotton fabrics [1] respectively. The undyed / unfinished untreated [UT] cotton fabric shows the maximum crease recovery (warp and weft) which is subsequently reduced after the treatments such as enzyme, morpholine and sodium hydroxide and subsequent dyeing and finishing. These treatments reduce the crease recovery on the cotton fabrics and sodium hydroxide treatment tops the list in this reduction followed by morpholine and enzyme treatments. Dyeing and finishing also further enhances the reduction in crease recovery on all these fabrics. The various dyes (Annatto, Onion, Pomogranate, Indigo, Myrobalan, Bar berry, Reactive Dye and Sulphur dye). do not give much influences in the differences of crease recovery. The weft directions have marginally more crease recovery values than those in
warp directions in all these woven cotton fabrics.

S.No.	Dyes	Crease recovery (°) of woven cotton fabric Warp (Cw)								
			1		2		3		4	
		UT	F1	F2	F1	F2	F1	F2	F1	F2
1	Undyed	112	109	107	99	96	104	100	107	104
2	Annatto	109	103	99	94	89	98	93	101	96
3	Onion	109	105	99	95	90	99	94	103	97
4	Pomogranate	110	106	100	96	89	101	94	104	97
5	Indigo	110	106	100	97	91	101	95	104	98
6	Myrobalan	110	105	100	95	91	99	95	103	98
7	Bar berry	109	104	98	94	88	98	92	101	95
8	Reactive Dye	104	100	96	91	87	94	91	97	94
9	Sulphur Dye	111	107	102	96	92	100	96	104	99
		Crease recovery (°) of woven cotton fabric Weft (Cf)								
		UT	1		2		3		4	
			F1	F2	F1	F2	F1	F2	F1	F2
1	Undyed	114	112	110	105	103	108	106	110	108
2	Annatto	111	104	102	97	95	100	98	102	100
3	Onion	111	107	104	100	97	103	100	105	102
4	Pomogranate	111	108	103	101	96	104	99	106	101
5	Indigo	112	108	104	102	97	104	100	106	102
6	Myrobalan	112	108	103	101	96	104	99	106	101
7	Bar berry	111	106	103	99	96	102	99	104	101
8	Reactive Dye	105	104	100	97	94	100	96	102	98
9	Sulphur Dye	113	109	105	100	97	104	100	107	103

TABLE 3. CREASE RECOVERY (°) OF DYED AND FINISHED WOVEN COTTON FABRIC

UT → undyed / unfinished / untreated cotton 1. Untreated cotton 2. Sodium hydroxide treated cotton
3. Morpholine treated cotton 4. Cellulase enzyme treated cotton

3.4.0 SEM analysis of cotton fabric

The analysis of SEM images of dyed and / or finished cotton fabrics (woven and knitted) have been discussed under this section. The dye was selected to dye some of the sample fabric based on the suitable performance. Accordingly, woven and knitted cotton fabrics were dyed with barberry dye**.** The fabrics were then finished and their respective SEM images were analyzed.

3.4.1 SEM analysis of woven cotton fabric

The SEM images of dyed and / or finished woven cotton fabrics (untreated, sodium hydroxide treated, morpholine treated and enzyme treated) are given in the Figures 1a, 1b, 1c, and 1d respectively. Figure 1 is the SEM image of untreated (undyed and unfinished) woven cotton fabric. As the samples were treated with different chemicals and subsequently dyed and finished, it is evident from the Figures 1a, 1b, 1c, and 1d respectively that there are some clear differences in the respective images. Accordingly, Figure 1a shows the SEM image of untreated

(dyed and finished) woven cotton fabric. Figures 1b, 1c, and 1d clearly give the differences in the corresponding SEM images about the influences of the respective chemical treatments on woven cotton fabric. Hence, the dyed and finished sodium hydroxide treated cotton fabric (Figure 1b) gives good appearance in the SEM image followed by morpholine treated (Figure 1c) and enzyme treated (Figure 1d) respectively.

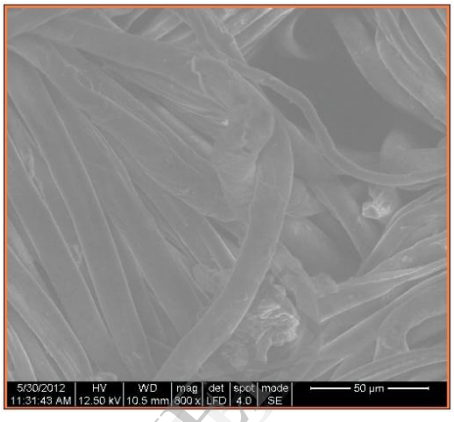

Fig. 1. SEM micrograph of undyed / unfinished untreated woven cotton fabric

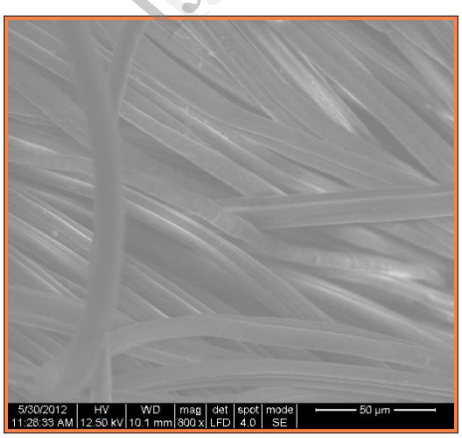

Fig. 1a. SEM micrograph of untreated, dyed and finished woven cotton fabrics

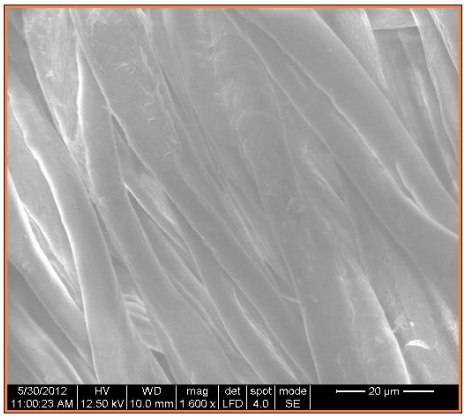

Fig. 1b. SEM micrograph of sodium hydroxide treated, dyed and finished woven cotton fabrics

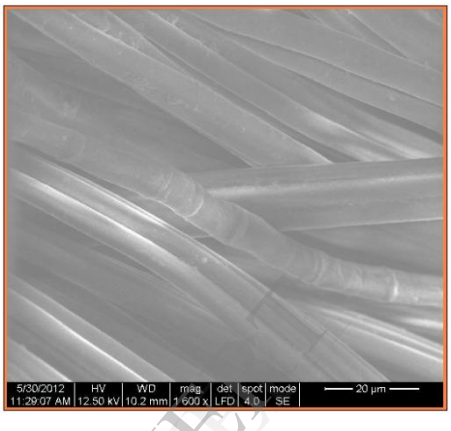

Fig. 1c. SEM micrograph of morpholine treated, dyed and finished woven cotton fabrics

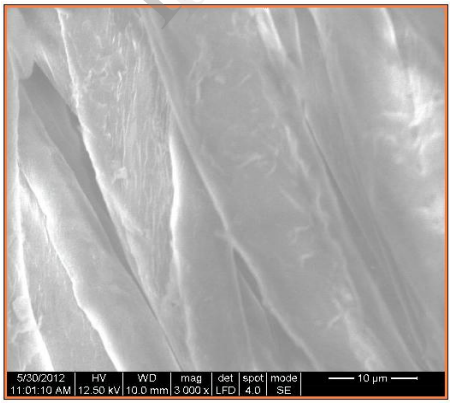

Fig. 1d. SEM micrograph of enzyme treated, dyed and finished woven cotton fabrics

3.4.2 SEM analysis of knitted cotton fabric

The SEM images of dyed and / or finished knitted cotton fabrics (untreated, sodium hydroxide treated, morpholine treated and enzyme treated) are given in the Figures 2a, 2b, 2c, and 2d respectively. Figure 2 is the SEM image of untreated (undyed and unfinished) knitted cotton fabric. As the samples were treated with different chemicals (sodium hydroxide, morpholine and enzyme) and subsequently dyed and finished, it is evident from the Figures 2a, 2b, 2c, and 2d respectively, that there are some clear differences in the respective images. Accordingly, Figure 2a shows the SEM image of untreated (dyed and finished) knitted cotton fabric. Figures 2b, 2c, and 2d clearly give the differences in the corresponding SEM images about the influences of the respective chemical treatments (sodium hydroxide, morpholine and enzyme) on knitted cotton fabrics. Hence, the dyed and finished sodium hydroxide treated cotton fabric (Figure 2b) gives good appearance in the SEM image followed by morpholine treated (Figure 2c) and enzyme treated (Figure 2d) respectively.

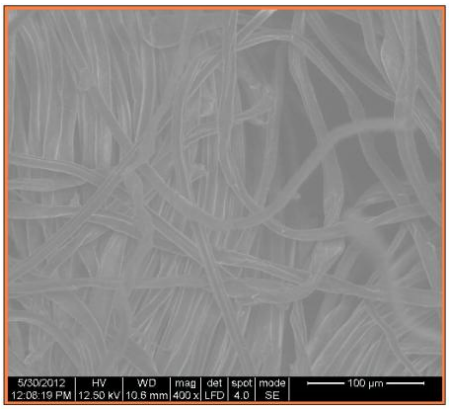

Fig. 2. SEM micrograph of undyed / unfinished untreated knitted cotton fabric

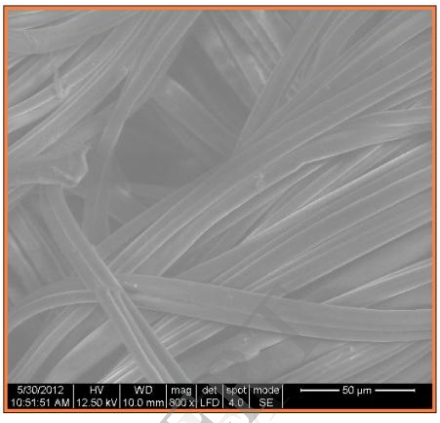

Fig. 2a. SEM micrograph of untreated, dyed and finished knitted cotton fabrics

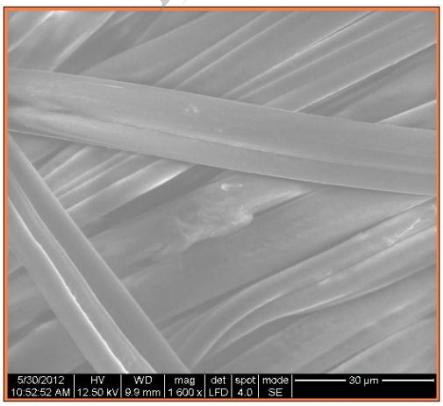

Fig. 2b. SEM micrograph of sodium hydroxide treated dyed finished woven cotton fabrics

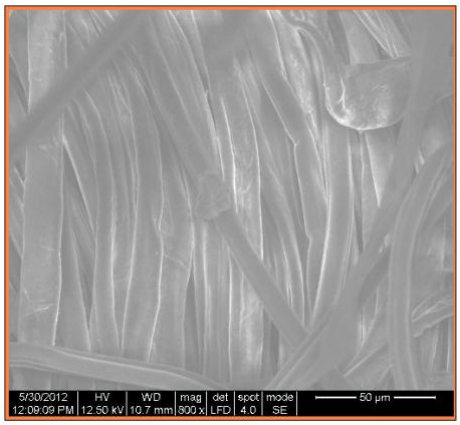

Fig. 2c. SEM micrograph of morpholine treated, dyed and finished woven cotton fabrics

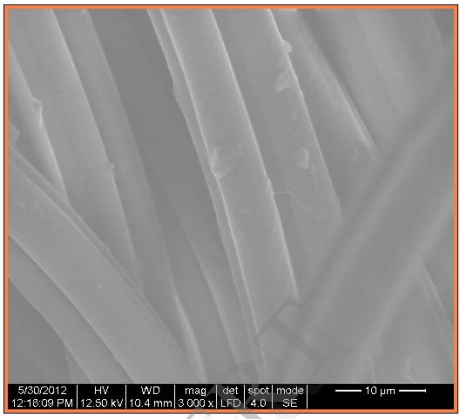

Fig. 2d. SEM micrograph of enzyme treated, dyed and finished knitted cotton fabrics

3.5 FTIR analysis of dyed woven cotton fabric

The cotton fabrics were dyed with different dyes. However as representation barberry dye was selected for dyeing on woven cotton fabric only. The FTIR graph of barberry in the intact form is given in Figure 3. Subsequently the FTIR graph of the same dye after application on the woven cotton fabric (untreated, chemical treated and dyed) are given in the Figures 3a, 3b, 3c, and 3d respectively; and those for the finished fabrics (untreated, chemical treated, dyed and finished) are given in the Figures 3e, 3f, 3g, and 3h respectively. The colour generated for barberry dye is yellow when applied on the cotton fabric. The FTIR graphs for this barberry dye (intact and dyed and finished) are shown in Figures 3, 3a, 3b, 3c, 3d, 3e, 3f, 3g, and 3h respectively and are analyzed as per the following data.

S.No.	Peak range(cm^{-1})	Functional groups
1	3600-3700	Non bonded hydroxyl group-OH-
2	3300-3400	Alkyne –C-H- stretch
3	3200-3300	Hydroxyl group (H-bonded –OH- stretch)
4	3000-3200	Aromatic ring (-C-H- stretch)
5	2900-3000	Methylene –CH- stretch
6	2700-2800	Terminal aldehyde –CH- stretch
7	2600-2700	Hydrogen bonded –OH- group
8	2500-2600	Thiols (-S-H- stretch)
9	2400-2500	-CH- stretch of aromatic compounds
10	2300-2400	-OH-stretching of Carboxylic acid

11	2200-2300	Cyano compounds,disubstituted alkynes
12	2100-2200	C-triple bond-C- stretch
13	2000-2100	Cyanide ion and related ion
14	1800-2000	Transition metal carbonyl group
15	1700-1800	Carbonyl group
16	1600-1700	-C-double bond-C stretch
17	1500-1600	Aromatic ring stretch-NH-bend
18	1400-1500	Organic Sulphates
19	1300-1400	-OH- bend
20	1200-1300	Aromatic primary amine –CN- stretch
21	1100-1200	Secondary amine –CN- stretch
22	1000-1100	-C-C- stretch
23	900-1000	Cyclo hexane ring vibrations
24	800-900	Peroxides -C-O-O-stretch
25	700-800	Skeletal –C-C- vibrations
26	600-700	Aliphatic Bromo compounds
27	500-600	-C-I- stretch

From these graphs it is evident that there are groups present in the barberry dye responsible for the reaction with the cotton textile fabric.

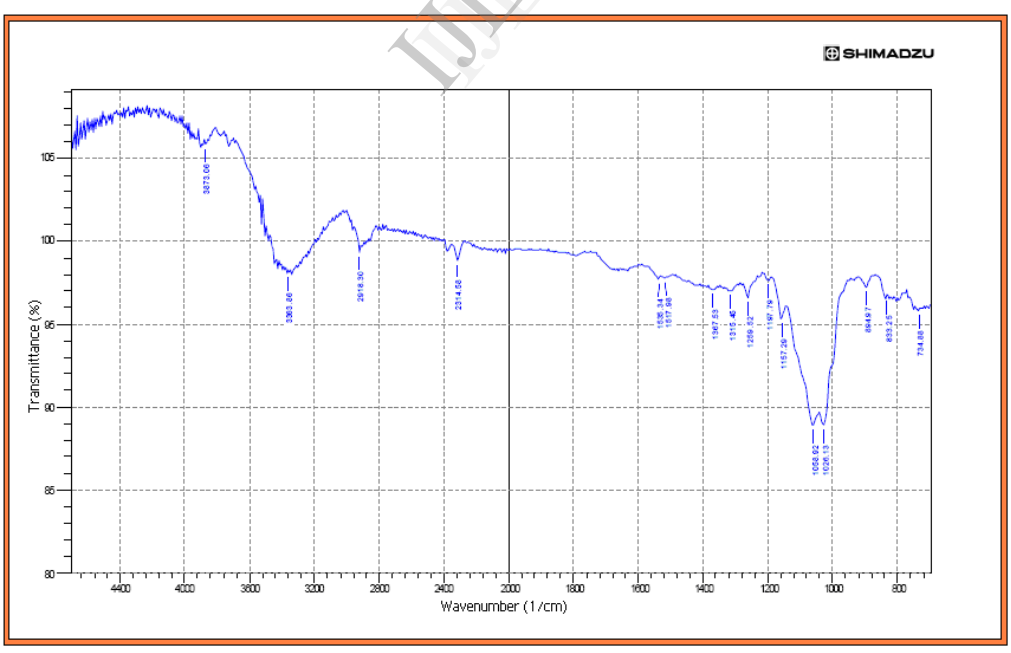

Fig. 3. FTIR spectra of barberry dye – yellow

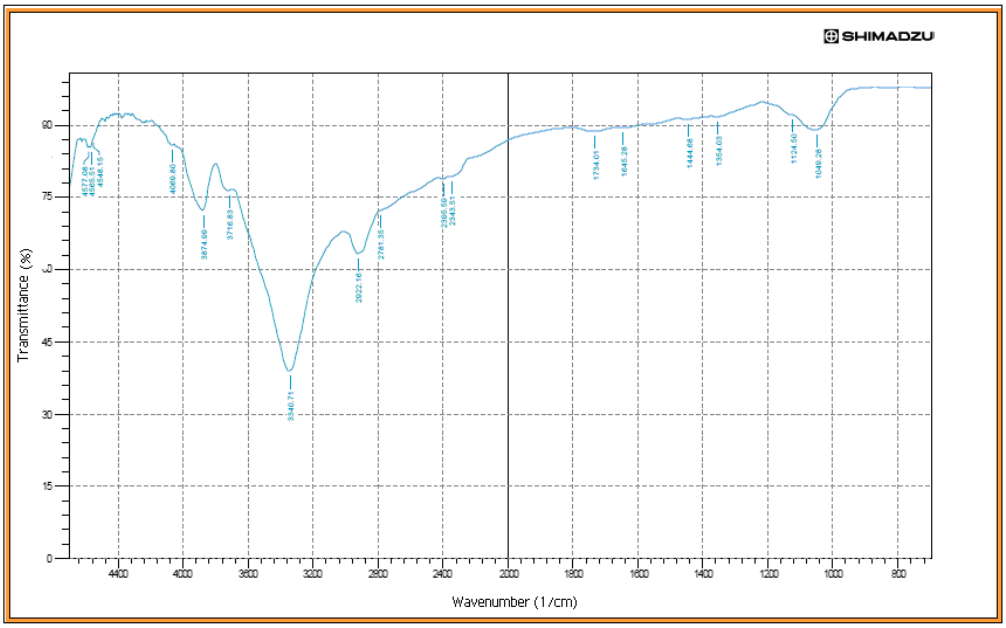

Fig. 3a. FTIR spectra of untreated and dyed woven cotton fabrics

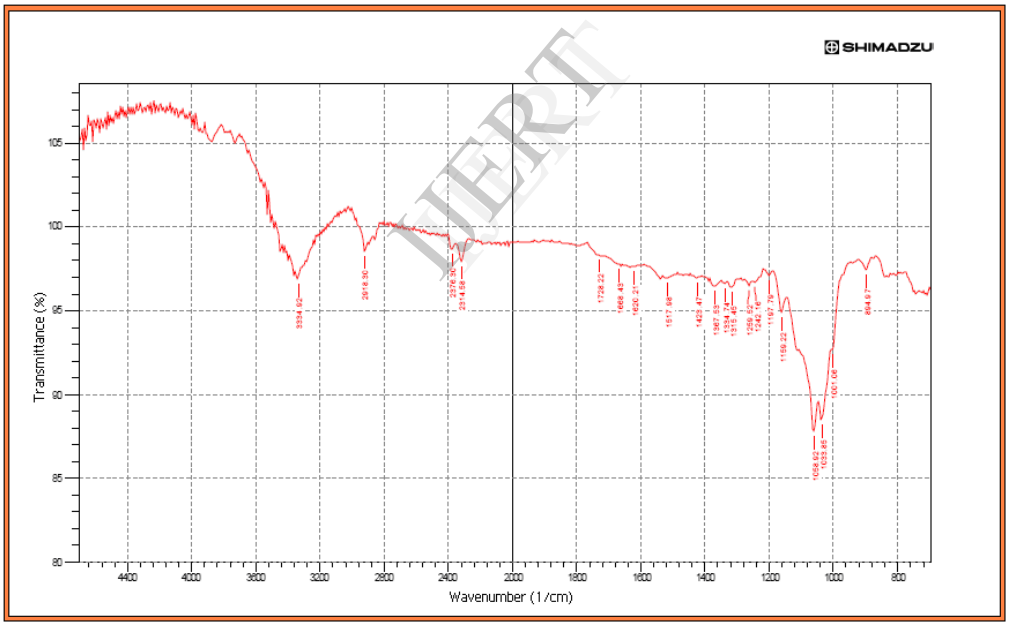

Fig. 3b. FTIR spectra of sodium hydroxide treated and dyed woven cotton fabrics

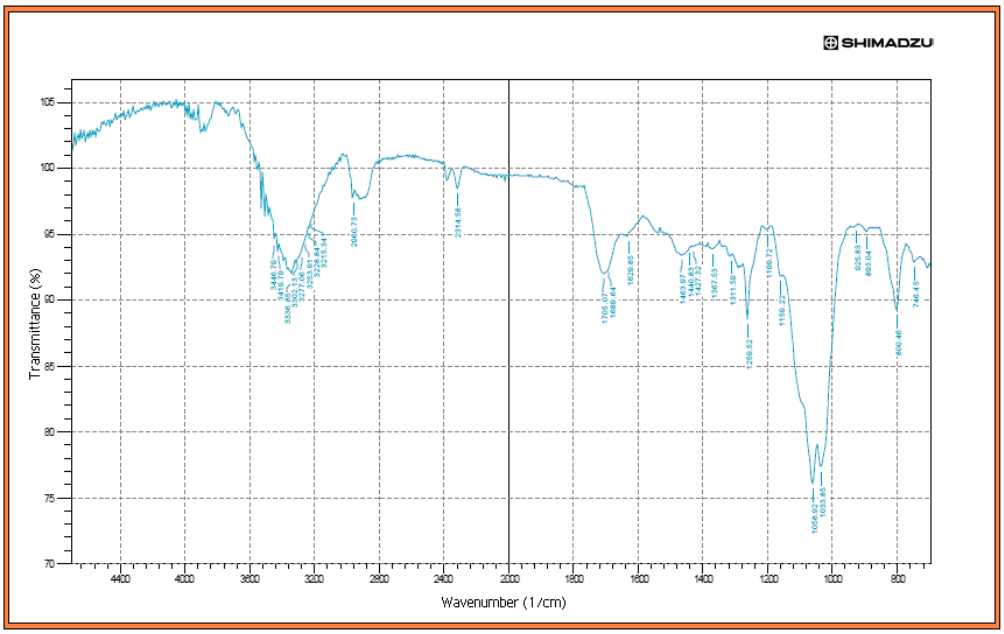

Fig. 3c. FTIR spectra of morpholine treated and dyed woven cotton fabrics

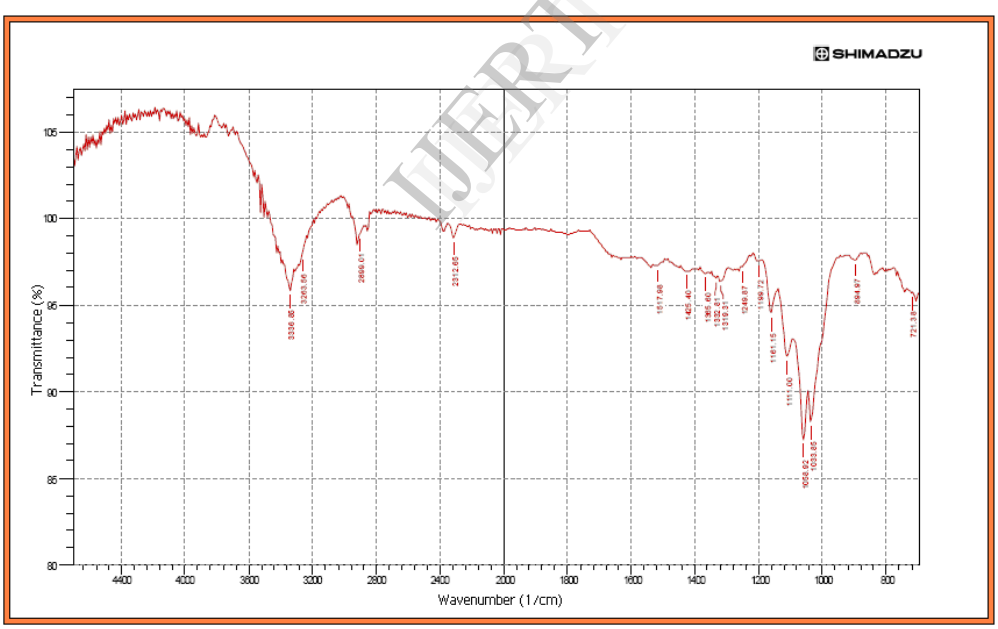

Fig. 3d. FTIR spectra of enzyme treated and dyed woven cotton fabrics

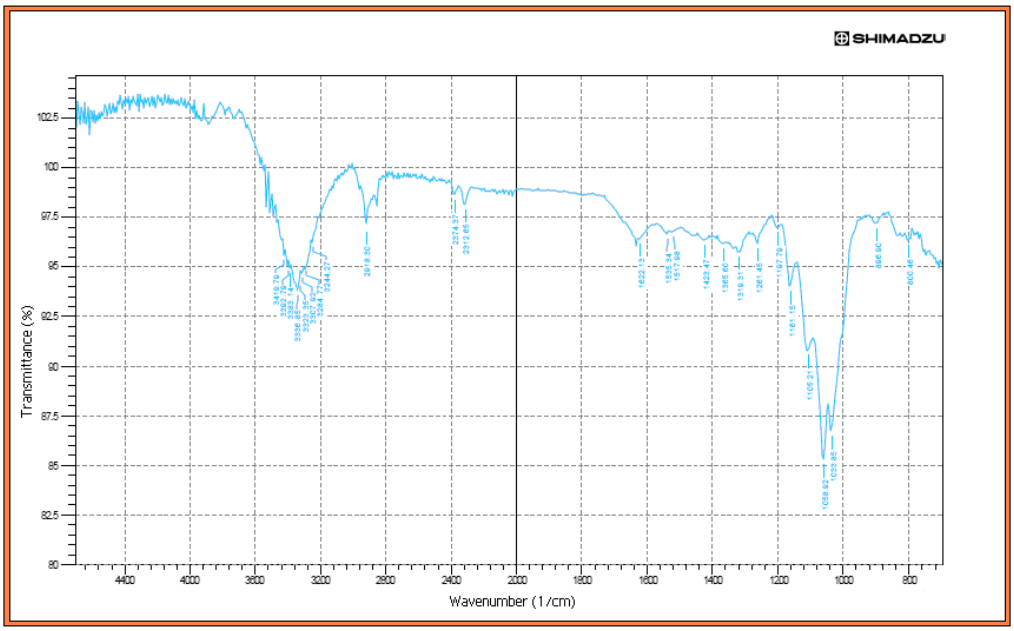

Fig. 3e. FTIR spectra of untreated, dyed and finished woven cotton fabrics

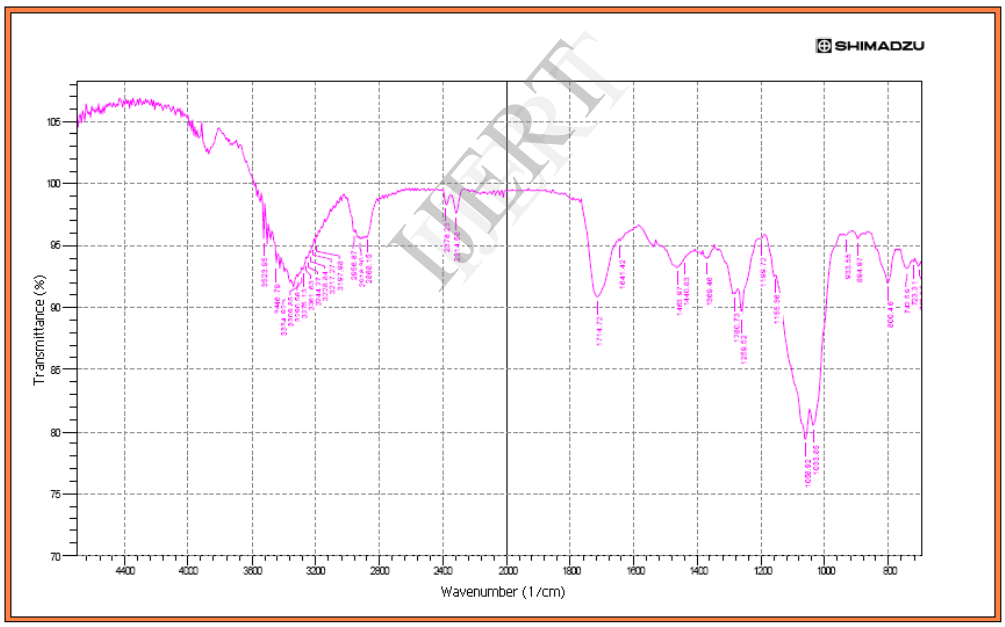

Fig. 3f. FTIR spectra of sodium hydroxide treated, dyed and finished woven cotton fabrics

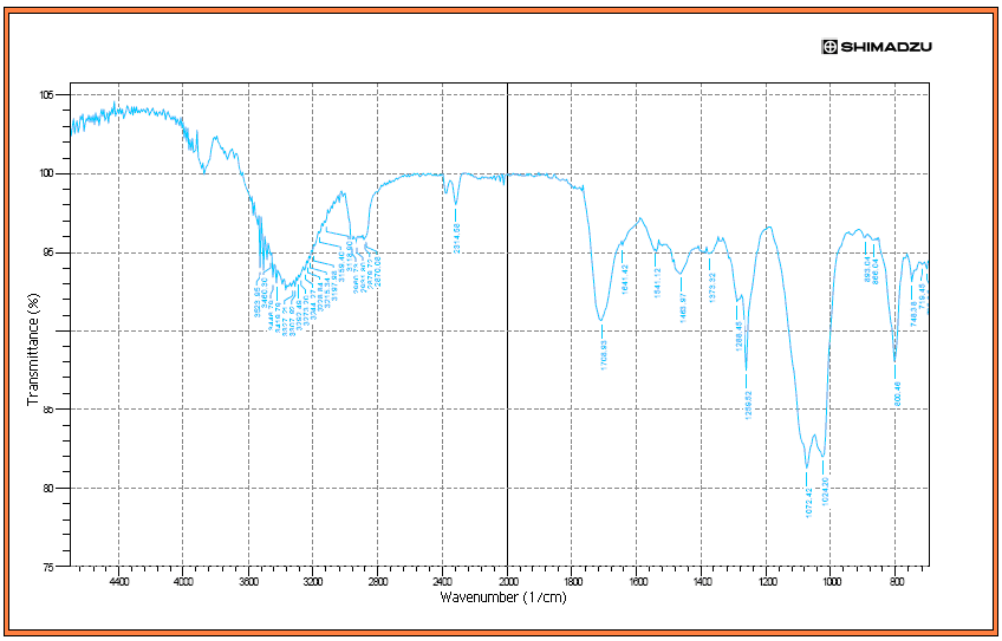

Fig. 3g. FTIR spectra of morpholine treated, dyed and finished woven cotton fabrics

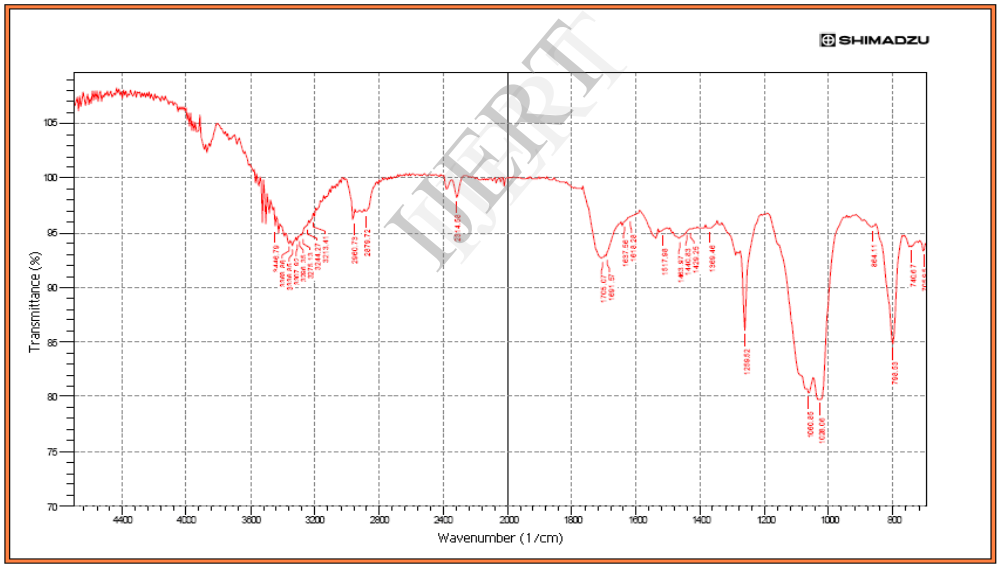

Fig. 3h. FTIR spectra of enzyme treated, dyed and finished woven cotton fabrics

4 CONCLUSION

The conclusions drawn from the study are summarized below:

The primary hand value such as smoothness, stiffness and fullness is good in sodium hydroxide treated, morpholine treated, enzyme treated woven and knitted cotton fabrics respectively. Smoothness is observed more on the dyed and finished sodium hydroxide treated cotton fabric followed by morpholine treated, enzyme treated and untreated cotton fabrics respectively. The sodium hydroxide treated cotton fabrics have reduced stiffness due to the generation of good flexibility; followed by morpholine treatment, enzyme treatment and untreated dyed and finished cotton fabrics. The fullness is also maximum on the sodium hydroxide treated cotton fabrics followed by morpholine treated, enzyme treated and untreated fabrics. In general, the primary hand value is maximum for the sodium hydroxide treated fabrics followed by morpholine treated, enzyme treated and untreated dyed and finished woven and knitted cotton fabrics.

The bending length in both warp and weft directions of dyed and finished woven cotton fabric is good in sodium hydroxide treated one with least value followed by morpholine treated, enzyme treated and untreated fabrics

respectively. The trend is common in both warp and weft directions, however the warp materials have an edge over the weft materials for the bending length.

The crease recovery in both warp and weft directions of dyed and finished woven cotton fabric treated with sodium hydroxide is minimum compared to morpholine treated, enzyme treated and untreated cotton fabric respectively revealed the good effect of sodium hydroxide. The trend is common in both warp and weft directions, however the weft materials have a little edge over the warp materials for the crease recovery.

SEM micrographs reveal that the dyed and finished sodium hydroxide treated cotton fabric gives good appearance followed by morpholine treated and enzyme treated respectively.

FTIR spectra prove that there are groups present in the barberry dye responsible for the reaction with the cotton textile fabric.

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