Study on Dyed Modal, Cotton and Modal/Cotton (50:50) Blend Fabrics for Assessing Antibacterial, Ant odor and UV Protection Behaviors

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Abstract **- Modal fabric is a cent percent bio-based rather than natural made from the spun reconstituted cellulose of beech trees. Modal fabrics resist fading, shrinking and the buildup of hard water mineral deposits even after repeated washing. Clothing today is expected to be insect repellent and antimicrobial to protect human beings from infection, UV light, chemical and biological agents. In this study, woven and knitted modal (100%), cotton (100%), and modal / cotton (50 : 50) blended fabrics were dyed with (kum kum, indigo and barberry) and synthetic dyed (reactive (H & M), and sulphur) dyes. They are then subjected for assessing antibacterial property, anti odor behavior, and UV protection performance.**

1. INTRODUCTION

Textiles and clothing should fulfill the functional, comfort, aesthetic safety and ecological requirements. Apparel makers and the finishing industry are thus faced with a daunting job of producing superior fabrics that are technically advanced[(4)]. Increasing concern over damage caused by exposure to microbes, chemicals, pesticides, UV light and pollutants in the last few years, has heightened the demand for protective garments. In many cases, protective garments have actually been known to impair user performance [(3)].

Cotton is a common material used for the production of textiles and garments suitable for various applications such as sportswear, functional wear, leisure wear, innerwear and other garments. Since cotton is non-allergic it doesn't irritate sensitive skin and preferred when worn close to the skin. It can imitate the feel and texture of silk, wool, cotton and linen. Rayon is used in the manufacturing of many apparels[(9,5,13)]. Modal is a 100 % biodegradable fabric made from the spun reconstituted cellulose of Beach trees. This fabric is bio-based, rather than natural. Fabric made from modal drape well and do not pile like cotton. It dyes like cotton and is color fast when washed in water. Modal fabrics resist fading, shrinking and the buildup of hard water mineral deposits even after repeated washing [(15,12,14)].

Antimicrobial property of textiles is being considered to be an important and inevitable parameter for garments which are in direct contact with human body. Natural textiles in contact with the human body offer an ideal environment for microbial growth. Microbial infestations possess danger to both living and non-living matters. The consumers are now increasingly aware of the hygienic life style and there is a necessity and expectation of a wide range of textile products finished with antimicrobial properties [(11)].

Aroma finish is the process by which textile materials are treated with the pleasant odor producing essential oils and aromatic compounds so that the wearer gets some beneficial effects. The pleasant smells created by the essential oils have pharmacological effects like antibacterial, antifungal, antiviral and mood elevating effects [(16)].

Skin cells that receive sunlight absorb harmful UV radiation, and slough off to excrete harmful UV from the body. But the absorption of too much UVR leads to scars that can induce diseases like skin cancer [(10)]. In this research paper, the modal, cotton and modal / cotton (50:50) blended fabrics dyed with natural and synthetic dyes were assessed for their antimicrobial, anti odor and UV protection behaviors.

2.0 MATERIALS AND METHODS

2.1.0 Materials

2.1.1 Textile fabric substrate. The textile fabrics used in this study were as follows:

I. Woven Fabrics

a) Modal (100%) : yarn count (both warp and weft) – 27, GSM - 146,
ends per inch – 84, picks per inch – 94,

b) Cotton (100%) : yarn count (both warp and weft) – 30, GSM - 137.2,
ends per inch – 94, picks per inch – 74; and

c) Modal / Cotton (50 : 50) blend : yarn count (both warp and weft) – 30, GSM - 142.7, ends per inch – 94, picks per inch – 77.

II. Knitted Fabrics

a) Modal (100%) : yarn count – 27.5, GSM 137, loop length–2.6 mm,

b) Cotton (100%) : yarn count – 30, GSM - 142, loop length–2.6 mm; and

c) Modal / cotton (50 : 50) blend : yarn count – 28.4, GSM 141.7, loop length–2.6 mm.

2.1.2 Dyes

a) Natural dyes

The natural dyes used in this study are; i) kum kum, ii) indigo, and iii) bar berry.

b) Synthetic dyes

The commercial synthetic dyes used in this study are; i) Reactive dye (H), ii) reactive dye (M) and iii) sulphur dye.

2.1.3 Chemicals and auxiliaries. The chemicals and auxiliaries mentioned elsewhere in this work are used as Analytical (AR) Grade.

2.2.0 Methods

2.2.1 Pretreatment on modal, cotton and modal / cotton (50 : 50) blended fabrics. The textile fabrics (woven and knitted) such as modal (100%), cotton (100%) and modal / cotton (50 : 50) blend were pretreated (scouring and bleaching) as per the established technique [5, 6].

2.2.2 Dyeing of modal, cotton and modal / cotton (50 : 50) blended fabrics. The dyeability of fabrics (woven and knitted) such as modal (100%), cotton (100%) and modal / cotton (50 : 50) blend 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 [8, 18]. The dyed samples were washed, soaped and dried.

2.2.3 Antibacterial finishing and testing. The modal, cotton and modal / cotton (50 : 50) blended fabrics were finished with antibacterial agent and the finished fabrics were tested according to AATCC standard methods against the standard test strains *Escherichia coli* and *Staphylococcus aureus*.

The processed fabrics were finished with the commercial antibacterial agent. The antibacterial agent Super FX AM 1000 was finished on the woven and knitted fabrics by diluting one portion of the antibacterial agent with one portion of water and the fabrics were immersed in the bath for 30 minutess at room temperature. The finished fabrics were squeezed and air – dried. The finished fabrics were then tested for the antibacterial activity [7, 9] by using standard test methods.

2.2.4 Organoleptic evaluation of odor control - after 48 hrs (In house method). The male panelists were each given a control and anti odor treated fabric sample daily during the test period. Each sample was worn on a specific foot. At the end of the workday, the panelists reported to the lab to remove the samples, seal them in plastic bags, and receive the samples for the next day. Five odor judges made odor evaluations [1, 16] 14 hour after removal of the sample on each test day. The judges used individual scoring sheets and new sheets were used every day of the evaluation. The odor grading scale was 10 to 0 (“no odor” to “very intense and disagreeable odor”).

2.2.5 UV protection finishing. The UV protection finishing was given to the knitted and woven modal, cotton and modal / cotton (50 : 50) blended fabrics and the finished fabrics were tested according to standard method. Super FX Anti UV was used for finishing the fabrics for UV protection property. The finishing agent was applied (Super FX Anti UV: 20-40 gpl, pH: 5, Pick up: 70 – 80%, Drying at:100 - 110˚C, Curing: 120 – 150˚C for 4 –7 min)on the fabric by padding method. The finished samples were tested [2, 17] for the UV protection property according to AATCC 183-1999.

3.0 RESULTS AND DISCUSSION

3.1 Antibacterial property of the modal, cotton and modal / cotton (50 : 50) blended woven and knitted dyed fabrics.

The data of antibacterial property of modal, cotton and modal / cotton (50 : 50) fabrics (woven and knitted) dyed with kum kum, indigo, bar berry, reactive dye (H), reactive dye (M) and sulphur dye for staphylococcus aureus and escherichia coli are given in Tables 1a and 1b respectively. The antimicrobial activity of these samples was assessed by qualitative test method (plate 1). All these dyed samples showed a higher zone of inhibition against staphylococcus aureus when compared to escherichia coli. In general, the modal fabric shows a higher zone of inhibition (both by staphylococcus aureus and escherichia coli) followed by modal / cotton (50 : 50) blended fabric and cotton fabric (woven and knitted). The reactive (H) dye shows maximum inhibition followed by reactive (M) dye and sulphur dye in synthetic dye category whereas indigo gives maximum inhibition followed by bar berry and kum dum in the natural dye category on modal, cotton and modal / cotton (50 : 50) blended fabrics (woven and knitted) exhibited by staphylococcus aureus and escherichia coli. The graphical representation is as shown in Figures 1a and 1b respectively.

Table 1a. Qualitative antibacterial assessment of dyed fabrics against staphylococcus aureus.

S. No.	Textile fabrics		Antibacterial activity (Zone of Bacteriostasis – mm) *Staphylococcus aureus*					
			Fabrics dyed with natural dyes			Fabrics dyed with synthetic Dyes		
			Kum kum	Indigo	Bar berry	Hot reactive	Cold reactive	Sulphur
1	Woven	Modal	33	37	35	45	43	39
2		Cotton	27	33	32	39	38	35
3		Cotton / modal	29	34	30	41	39	37
4	Knitted	Modal	32	35	33	43	41	38
5		Cotton	26	31	28	38	36	34
6		Cotton / modal	28	33	30	40	38	36

Figure 1a. Qualitative antibacterial assessment of dyed fabrics against staphylococcus aureus.

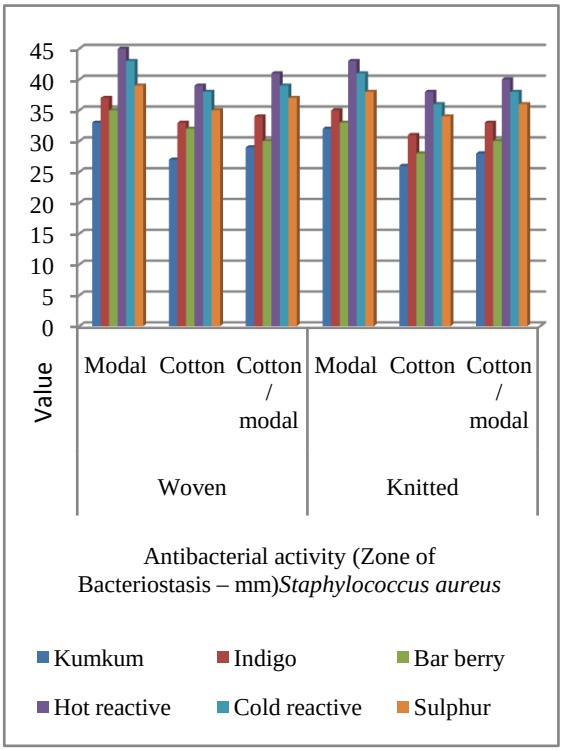


Table 1b. Qualitative antibacterial assessment of dyed fabrics against *Escherichia coli*

S. No.	Textile fabrics		Antibacterial activity (Zone of Bacteriostasis – mm) *Escherichia coli*					
			Fabrics dyed with natural dyes			Fabrics dyed with synthetic dyes		
			Kum kum	Indigo	Bar berry	Hot reactive	Cold reactive	Sulphur
1	Woven	Modal	30	35	32	43	40	38
2		Cotton	27	30	28	34	33	32
3		Cotton / modal	28	31	30	38	36	35
4	Knitted	Modal	28	34	30	40	38	37
5		Cotton	25	29	26	32	30	30
6		Cotton / modal	26	30	29	36	34	33

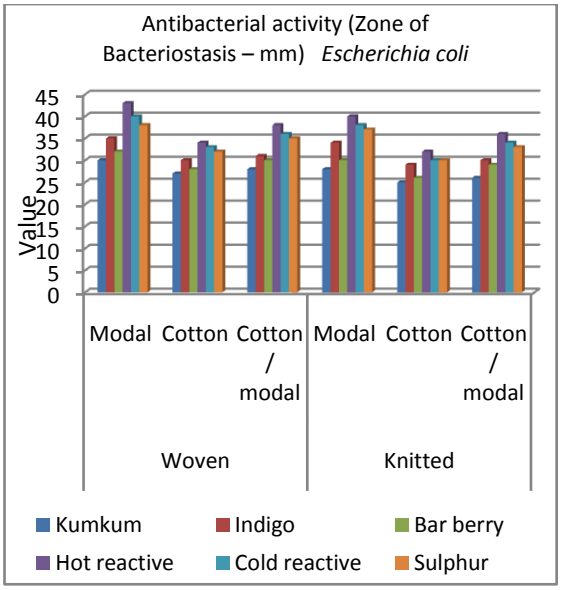
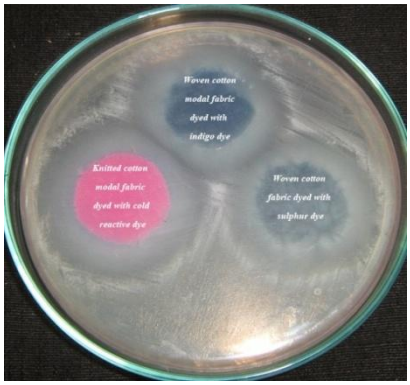
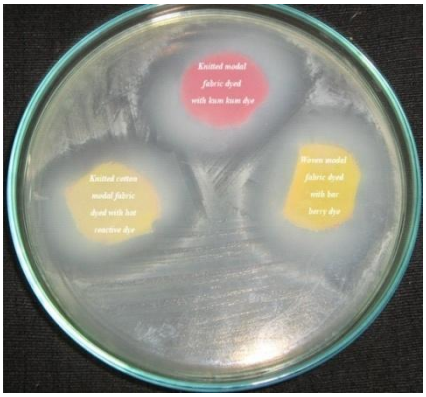


Figure 1b. Qualitative antibacterial assessment of dyed fabrics against *Escherichia coli.*

Plate 1. Antibacterial activity of dyed fabrics by disc diffusion method Antibacterial activity against *Staphylococcus aureus.*





3.2 Anti odor behavior of the modal, cotton and modal / cotton (50 : 50) blended woven and knitted dyed and anti odor finished fabrics.

The fabrics (modal, cotton and modal / cotton (50 : 50) blend woven and knitted) finished with the anti odor agent were assessed by subjective evaluation technique performed by five judges (for men, women and children) of different age categories and the odor grading was rated between 0 and 10. Based on the performances of the natural and synthetic dyes the dyeing was carried out on the suitable materials. Accordingly in the woven fabrics, modal was dyed with barberry, cotton with sulphur and modal/cotton (50 : 50) blend with indigo dyes whereas in the knitted fabrics, modal was dyed with kum kum, cotton with reactive [M] and modal/cotton (50 : 50) blend with reactive [H] dyes respectively. The data of anti odor assessment performed by men, women and children on the dyed and finished modal, cotton and modal / cotton (50 : 50) blended woven and knitted fabrics are given in Tables 2a, 2b and 2c respectively.

3.2.1 Anti odor behavior of the modal, cotton and modal / cotton (50 : 50) blended woven and knitted dyed and anti odor finished fabrics (assessed by men)

The data of anti odor assessment performed by men on the modal, cotton and modal / cotton (50 : 50) blended woven and knitted dyed and anti odor finished fabrics are given in Table 2a. The fabrics were evaluated by five judges (men) of different age categories, from 25 years to 50 years with non uniform heights and weights. Among the men fabrics the maximum average anti odor assessment value is for modal fabric dyed by barberry which gives the rating of 8-9 (very good to excellent) followed by modal / cotton (50 : 50) blend dyed by indigo (rating of 8; very good) and cotton dyed by sulphur (rating of 7 – 8; good to very good). Whereas in the knitted fabrics the trend is quite changed. The modal / cotton (50 : 50) blend dyed by reactive [H] gives the rating of 9 (excellent) followed by cotton (7-8; good to very good) dyed by reactive [M] and modal (7 ; good) dyed by kum kum. The average anti odor behavior of these fabrics is in general very good as revealed by the Table 2a. The graphical representation is as shown in Figure 2a.

Table 2a. Anti odor behavior of the modal, cotton and modal / cotton (50 : 50) blended woven and knitted dyed and anti odor finished fabrics(assessed by men)

Assessment by judges	Dyed and finished woven fabric.						Dyed and finished Knitted Fabric.					
	Modal (Barberry)		Cotton (Sulphur)		Modal / Cotton (Indigo)		Modal (Kum Kum)		Cotton (Reactive[M])		Modal/ Cotton (Reactive [H])	
	A	B	A	B	C	D	C	D	E	F	E	F
Jud I	9	9	7	8	9	8	7	5	6	7	8	9
Jud II	9	8	8	6	9	8	8	7	7	8	9	9
JudIII	9	8	8	6	7	7	8	8	8	9	9	9
JudIV	8	7	7	7	7	8	6	6	7	6	9	8
JudV	9	7	8	7	8	7	7	8	7	9	9	9
Ave	9	8	8	7	8	8	7	7	7	8	9	9

A => Height – 178 cm, Weight – 82 Kg, Age – 50 years
B => Height – 174 cm, Weight – 70 Kg, Age – 35 years
C => Height – 174 cm, Weight – 73 Kg, Age – 45 years
D => Height – 170 cm, Weight – 68 Kg, Age – 30 years
E => Height – 172 cm, Weight – 72 Kg, Age – 40 years
F => Height – 168 cm, Weight – 65 Kg, Age – 25 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

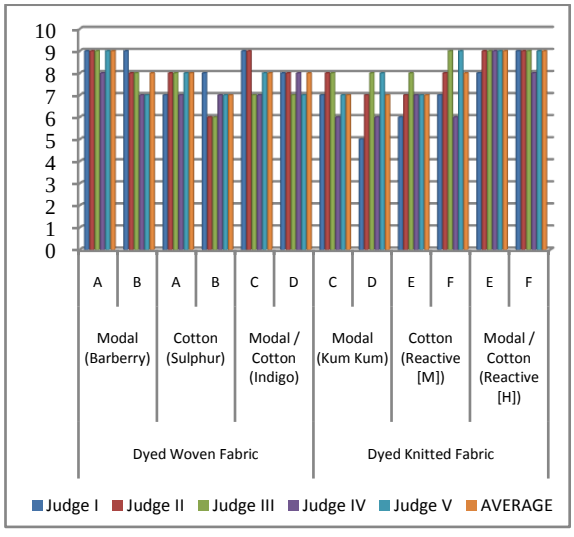


Figure 2a. Anti odor behavior of the modal, cotton and modal / cotton (50 :50) blended woven and knitted dyed and anti odor finished fabrics (assessed by men).

3.2.2 Anti odor behavior of the modal, cotton and modal / cotton (50 : 50) blended woven and knitted dyed and anti odor finished fabrics (assessed by women)

The data of anti odor assessment performed by women on the modal, cotton and modal / cotton (50 : 50) blended woven and knitted dyed and anti odor finished fabrics are given in Table 2b. The fabrics were evaluated by five judges (women) of different age categories, from 25 years to 48 years with non uniform heights and weights. Among the woven fabrics the maximum average anti odor assessment value is for modal (dyed by barberry) and modal / cotton (50 : 50) blend (dyed by indigo) that gives the rating of 8 (very good) followed by cotton dyed by sulphur (rating of 7; good). Whereas in the knitted fabrics the trend is different. The modal / cotton (50 : 50) blend dyed by reactive [H] gives the rating of 8-9 (very good to excellent) followed by cotton (7-8; good to very good) dyed by reactive [M] and modal (7 ; good) dyed by kum kum. From Table 2b it is clear that the anti odor behaviour of modal, cotton and modal / cotton (50 : 50) woven and knitted fabrics is very good when dyed by suitable dyes and finished accordingly. The graphical representation is as shown in Figure 2b.

Table 2b. Anti odor behavior of the modal, cotton and modal / cotton (50:50) blended woven and knitted dyed and anti odor finished fabrics (assessed by women)

Assessment by Judges	Dyed and finished woven fabric						Dyed and finished knitted fabric					
	Modal (Barberry)		Cotton (Sulphur)		Modal / Cotton (Indigo)		Modal (Kum Kum)		Cotton (Reactive [M])		Modal / Cotton (Reactive [H])	
	A	B	A	B	C	D	C	D	E	F	E	F
Judge I	9	8	8	6	8	7	7	7	7	8	9	8
Judge II	8	7	7	8	8	8	7	7	7	6	9	7
Judge III	8	7	8	7	9	8	7	8	7	8	9	8
Judge IV	8	7	7	6	6	7	7	7	6	9	9	9
Judge V	9	9	7	8	8	8	8	7	9	8	8	8
Average	8	8	7	7	8	8	7	7	7	8	9	8

A => Height – 172 cm, Weight – 70 Kg, Age – 48 years
B => Height – 160 cm, Weight – 55 Kg, Age – 35years
C => Height – 168 cm, Weight – 65 Kg, Age – 45 years
D => Height – 164 cm, Weight – 60 Kg, Age – 32years
E => Height – 162 cm, Weight – 62 Kg, Age – 40 years
F => Height – 165 cm, Weight – 58 Kg, Age – 25 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

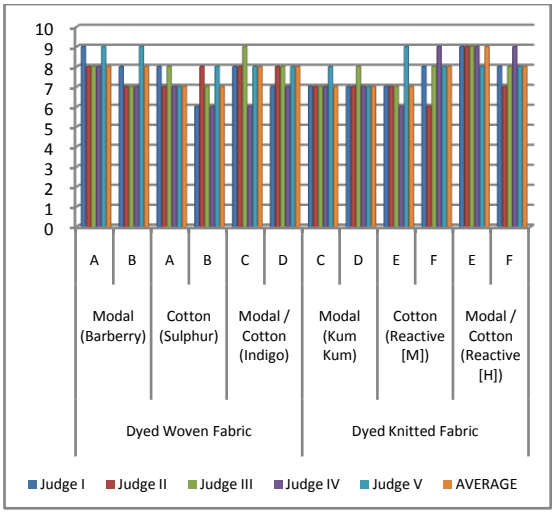


Figure 2b. Anti odor behavior of the modal, cotton and modal / cotton (50:50) blended woven and knitted dyed and anti odor finished fabrics (assessed by women).

3.2.3 Anti odor behavior of the modal, cotton and modal / cotton (50 : 50) blended woven and knitted dyed and anti odor finished fabrics (assessed by children).

The data of anti odor assessment performed by children on the modal, cotton and modal / cotton (50 : 50) blended woven and knitted dyed and anti odor finished fabrics are given in Table 2c. The fabrics were evaluated by five judges (children) of different age categories, from 5 years to 14 years with non uniform heights and weights. Among the children fabrics the maximum average anti odor assessment value is for modal (dyed by barberry) and cotton / modal (50 : 50) blend (dyed by indigo) that gives the rating of 7-8 (good to very good) followed by cotton dyed by sulphur (rating of 7; good). Whereas different behavior is obtained in the knitted fabrics. The modal / cotton (50 : 50) blend dyed by reactive [H] gives the rating of 7-8 (good to very good) followed by cotton (7; good) dyed by reactive [M] and modal (6-7 ; fairly good to good) dyed by kum kum. From Table 2c it is seen that there is a good anti odor behavior on modal, cotton and modal / cotton (50 : 50) blend woven and knitted fabrics when dyed by suitable dyes and finished accordingly. The graphical representation is as shown in Figure 2c.

Table 2c. Anti odor behavior the modal, cotton and modal / cotton (50 : 50) blended woven and knitted dyed and anti odor finished fabrics (assessed by children)

Assessment by Judges	Dyed Woven Fabric						Dyed Knitted Fabric					
	Modal (Barberry)		Cotton (Sulphur)		Modal / Cotton (Indigo)		Modal (Kum Kum)		Cotton (Reactive [M])		Modal / Cotton (Reactive [H])	
	A	B	A	B	C	D	C	D	E	F	E	F
Judge I	9	7	7	7	9	8	7	7	8	7	8	8
Judge I	7	7	8	6	8	6	7	5	7	6	8	9
Judge III	8	8	6	6	7	7	6	7	7	7	6	7
Judge IV	8	7	7	7	8	8	7	6	6	6	7	8
Judge V	9	7	6	7	8	7	7	6	7	8	7	7
AVERAGE	8	7	7	7	8	7	7	6	7	7	7	8

A => Height – 162 cm, Weight – 48 Kg, Age – 14 years
B => Height – 128 cm, Weight – 25 Kg, Age – 9 years
C => Height – 145 cm, Weight – 36 Kg, Age – 12 years
D => Height – 105 cm, Weight – 20 Kg, Age – 7 years
E => Height – 134 cm, Weight – 30 Kg, Age – 10 years
F => Height – 92 cm, Weight – 15 Kg, Age – 5 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

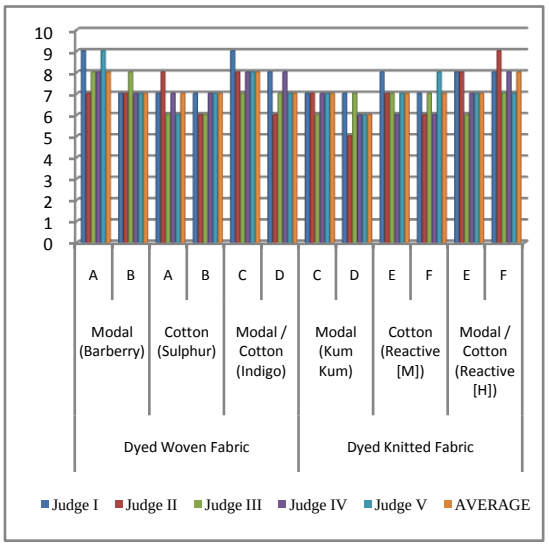


Figure 2c. Anti odor behavior of the modal, cotton and modal / cotton (50 :50) blended woven and knitted dyed anti odor finished fabrics (assessed by children)

3.3 Antiodour retention behavior and release rate of the modal, cotton and modal / cotton (50 : 50) blended woven and knitted dyed and anti odor finished fabrics.

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

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

The table and the graphical representation is as shown in the Table 3 and Figure 3.

The concentration of antiodor agent was tested on woven and knitted modal, cotton and modal / cotton (50 : 50 blend) fabrics and the rate of release of the fragrance was determined as mg/g and as percentage respectively. The woven modal fabric dyed with bar berry shows maximum concentration of the antiodor agent and rate of release of the antiodor agent. Similarly,in the knitted fabric also, modal dyed by kum kum shows the higher cnecentration and the rate of release of the anti odor agent.

Table 3. Antiodor retention behavior and release rate of the modal, cotton and modal / cotton (50:50) blended woven and knitted dyed and anti odor finished fabrics.

Anti odour retention behaviour (mg/g) and release rate (%)of the dyed and finished fabrics.		Dyed and finished woven fabric.			Dyed and finished knitted fabric.		
		Modal (Barberry)	Cotton (Sulphur)	Modal / Cotton (Indigo)	Modal (Kum Kum)	Cotton (Reactive [M])	Modal / Cotton (Reactive [M])
Retention of anti odour agent on the fabrics (mg/g)	Immediately	325.87	312.59	297.71	308.78	298.54	285.47
	After 4 days	294.58	267.48	247.96	267.75	258.63	257.15
	After 8 days	256.78	217.72	227.72	223.42	238.41	206.87
Release rate of anti odour agent from the fabrics (%)	After 4 days	18.9	14.4	13.6	14.9	13.8	12.7
	After 8 days	21.7	18.6	17.9	18.2	18.4	17.0

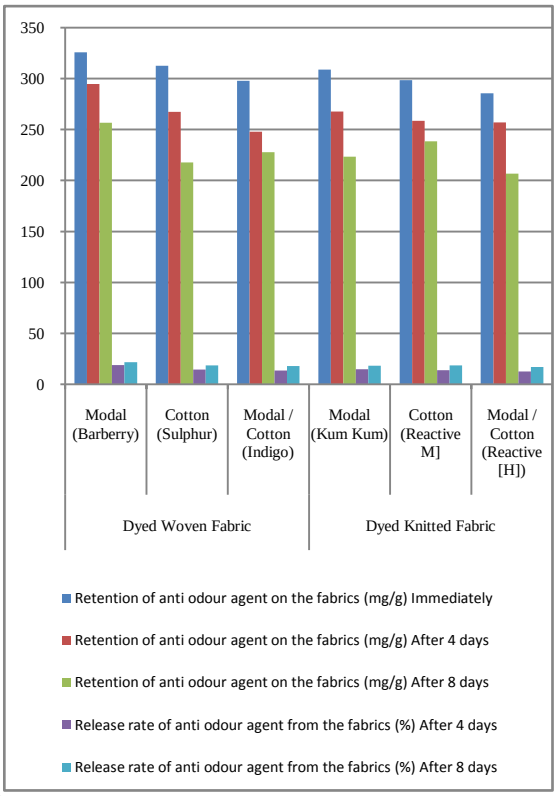


Figure 3. Anti odour retention behavior and release rate of the modal, cotton and modal / cotton (50:50) blended woven and knitted dyed and anti odor finished fabrics.

3.4 UV protection testing on modal, cotton and modal / cotton (50 : 50) blended woven and knitted dyed and UV protection finished fabrics.

The UV transmittance of the finished fabric samples (modal, cotton and modal / cotton (50 : 50) blended were determined using UV visible spectrophotometer. The standard chart for determining the UV protection factor is presented in the Table 4a, and the data of UV protection factor for the finished modal, cotton and modal / cotton (50 : 50) blend woven and knitted fabrics are given in Table 4b.

3.4.1 Standard chart for UPF rating for the fabric

The standard chart for determining the UV protection factor as shown in Table 4a shows that the percentage of UV radiation blocked ranged from 93.3 - 95.9 for the rating between 15 to 24 gives good protection category. Similarly, percentage UV blocked ranged from 96 - 97.4 for UPF rating of 25 to 39 brings very good protection category. With percentage UV radiation blocked ranging from 97.5 or more, the UPF rating ranges from 40 to 50 leads excellent protection category.

Table 4a. Standard chart for UPF rating for the fabric

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

3.4.2 UV protection factor for the modal, cotton and modal / cotton (50 : 50) blended woven and knitted dyed and UV protection finished fabrics.

The UV protection factor for the modal, cotton and modal / cotton (50 : 50) blended woven and knitted dyed and UV protection finished fabrics is given in Table 4b. The UV protection factor (UPF) values of all the dyed and finished fabrics are between 29 and 39 respectively. The maximum UPF value (39) is given by woven modal fabric dyed with indigo (natural) dye whereas the minimum UPF value (29) is seen in knitted cotton fabric dyed by barberry (natural) dye. In general woven modal dyed and finished fabric shows maximum UPF rating followed by modal / cotton (50 : 50) blend and cotton fabrics respectively. The same trend is also followed for knitted fabrics, however woven fabrics have an edge over the knitted fabrics. From these data (Table 4a) it is clear that there is a very good UV protection category as revealed by UPF rating (29 – 39) for the dyed and finished modal, cotton and modal / cotton (50 : 50) woven and knitted fabrics (Table 4b). Therefore based on this, as indicated in the Table 4a the percent UV radiation blockage by these fabrics (dyed and finished modal, cotton and modal / cotton (50 : 50) woven and knitted fabrics) (Table 4b) would be between 96% and 97.4%. The graphical representation is as shown in the Figure 4.

Table 4b. UV Protection factor for the modal, cotton and modal / cotton (50 : 50) blended woven and knitted dyed and UV protection finished fabrics

S. No.	Dyes	UPF rating of the dyed and finished fabrics					
		Woven			Knitted		
		Modal	Cotton	Modal / Cotton (50 : 50)	Modal	Cotton	Modal / Cotton (50 : 50)
1	Kum kum	36	33	35	34	31	32
2	Indigo	39	34	36	35	31	33
3	Barberry	33	31	32	32	29	30
4	Reactive Dye (H)	34	30	32	31	30	31
5	Reactive dye (M)	34	30	31	31	30	30
6	Sulphur Dye	33	30	32	30	30	30

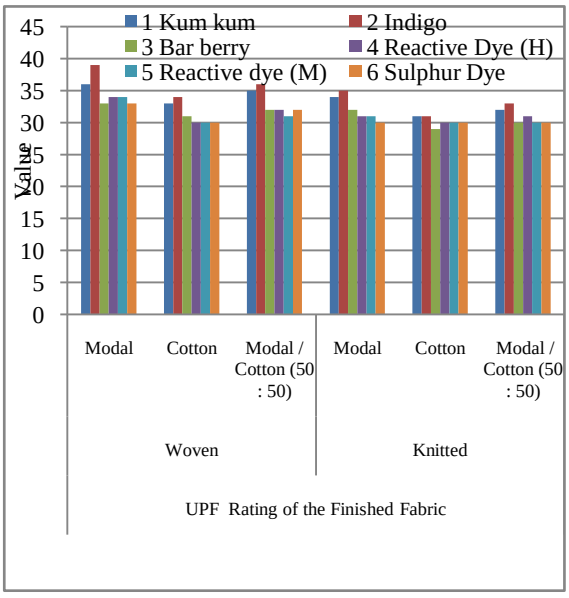


Figure 4. UV Protection factor for the modal, cotton and modal / cotton (50 : 50) blended woven and knitted dyed and UV protection finished fabrics.

4. CONCLUSION"

In this work, the modal and modal / cotton (50 : 50) blended fabrics (woven and knitted) were studied and compared with cotton fabric. The conclusions drawn from the study are summarized below:

The dyed samples had a higher zone of inhibition against Staphylococcus aureus when compared to Escherichia coli. In general, the modal fabric shows a higher zone of inhibition (both by Staphylococcus aureus and Escherichia coli) followed by modal / cotton (50 : 50) blend fabric and cotton fabric (woven and knitted). The reactive (H) dye shows maximum inhibition followed by reactive (M) dye and sulphur dye in synthetic dye category whereas indigo gives maximum inhibition followed by bar berry and kum dum in the natural dye category on modal, cotton and modal / cotton (50 : 50) blended fabrics (woven and knitted) exhibited by staphylococcus aureus and escherichia coli.

The anti odor assessment value (performed by men, women and children) is maximum for woven modal fabric dyed by barberry followed by modal / cotton (50 : 50) blend dyed by indigo and cotton dyed. In the knitted fabrics the trend is quite changed. The modal / cotton (50 : 50) blend dyed by reactive [H] dye gives more value followed by cotton dyed by reactive [M] and modal dyed by kum kum. The woven modal fabric dyed with bar berry shows maximum concentration of the antiodor agent and rate of release of the antiodor agent. In the knitted fabric also, modal dyed by kum kum shows the higher concentration and the rate of release of the anti odor agent.

The woven modal dyed and finished fabric shows maximum UPF rating followed by modal / cotton (50 : 50) blend and cotton fabrics respectively. The same trend is also followed for knitted fabrics, however woven fabrics have an edge over the knitted fabrics.

Based on these points, it is finally concluded that the modal fabric in its original (100%) form and also in blend with cotton (50 : 50) exhibited very good results, in no way inferior to cotton. Hence, the fabrics from modal and modal / cotton (50 :50) blend could be best utilized for different varieties of garments and textile products.

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