

## **STUDY OF ANTIMICROBIAL EFFECT ON MODAL FABRIC AND ITS COTTON COUNTERPART DYED WITH SOME NATURAL DYES AND SYNTHETICS DYES**

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### **ABSTRACT**

Nowadays, modal fibre is considered important due to its overall performances similar to cotton, as well as its eco friendly attributes. In this study, modal was considered in its intact and blend form and they were compared with cotton fabric. The fabrics were tested for absorbency, wicking, dye ability antibacterial activity. The dyes such as kum kum, indigo, bar berry (natural dyes); and reactive (hot and cold) and sulphur dyes (synthetic) respectively were used for dyeing on cotton, modal, cotton / modal (50 : 50 blend) fabrics. The study revealed that modal contributes the properties not inferior to that of cotton.

**KEY WORDS :** Modal, kum kum, bar berry, wicking, antimicrobial activity

### **1. INTRODUCTION**

Consumers' attitude towards hygiene and active lifestyle has created a rapidly increasing market for a wide range of antimicrobial textiles, which in turn has stimulated intensive research and development. As a result, the number

of biofunctional textiles with an antimicrobial activity has increased considerably over the last few years<sup>1</sup>.

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<sup>2</sup>. Due to the increasing awareness of environmental aspects and requirement of ecofriendly processing, the new trend of producing "Organic Cotton", is setting in<sup>3</sup>. Cotton's adaptability allows it to blend easily with most other fibers including lyocell. Cotton is one of the easiest fabrics to dye, making it very popular with fashion and home ware designers. Cotton has a high absorbency<sup>4</sup> rate and holds up to 27 times its own weight in water. However, the moist cotton can be easily attacked by bacteria. Decomposed products of body secretions have a characteristic odor<sup>5</sup>.

Modal is a 100 % biodegradable fabric made from the spun reconstituted cellulose of Beach trees. This fabric is bio-based, rather than natural. The reason for this is that although the fabric is made from natural raw material it undergoes chemical processing. Modal fabrics are very soft and smooth with the ability to absorb up to 50% more water than cotton. 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<sup>6,7,8</sup>.

Antimicrobial textiles have been tested for use in the medical industry for some time. Currently, the only antimicrobial textiles being used in the field of medicine are disposable and nonwoven<sup>9</sup>. Some of the treatments being used are harmful to our environment not only because of the chemicals used in the treatments but also because the treated textiles are not reusable. To address the growing concerns about the environment, researches are focused on the use of

reusable textiles with durable finishes<sup>10</sup>. With growth 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. The need for antimicrobial textiles goes hand-in-hand with the rise in resistant strains of microorganisms<sup>5,6</sup>. The present study focused on the development of woven and knitted cotton, modal and cotton / modal (50 : 50 blend) fabrics. The fabrics were dyed using both natural dyes (kum kum, indigo and bar berry) and synthetic dyes (reactive and sulphur) and the dyed fabrics were subjected to antimicrobial finish. The antimicrobial efficiency was tested using standard methods and the results were compared.

## **2. MATERIALS AND METHODS**

### **2.1 Materials**

The textile fabrics used in this study were as follows;

- I) Woven Fabrics: a) Cotton (100%) : yarn count (both warp and weft) – 30, GSM - 137.2, ends per inch – 94, picks per inch – 74; b) Modal (100%) : yarn count (both warp and weft) – 27, GSM - 146, ends per inch – 84, picks per inch – 94; and c) Cotton / Modal blend (50 : 50) : yarn count (both warp and weft – 30, GSM - 142.7, ends per inch – 94, picks per inch – 77
- II) Knitted Fabrics: a) Cotton (100%) : yarn count – 30, GSM - 142, loop length–2.6 mm; b) Modal (100%) : yarn count – 27.5, GSM 137, loop length–2.6 mm; and c) Cotton / Modal blend (50 : 50) : yarn count – 28.4, GSM 141.7, loop length–2.6 mm.

Natural dyes (kum kum, indigo, bar berry) and synthetic dyes (reactive dye (H), reactive dye (M) and sulphur dye) used were in the commercial grade. The chemicals mentioned elsewhere for this study were in AR grade.

## **2.2 Methods**

### **2.2.1 Pretreatment on cotton, modal and cotton / modal blend fabrics**

The textile fabrics (woven and knitted) such as cotton (100%), modal (100%) and cotton / modal (50 : 50) were pretreated (scouring and bleaching) as per the established technique<sup>11, 12</sup>.

### **2.2.2 Absorbency of cotton, modal and cotton / modal blend fabrics**

The absorbency<sup>13, 14</sup> of the textile fabrics (woven and knitted) such as cotton (100%), modal (100%) and cotton / modal (50 : 50) was determined by the drop absorbency method according to AATCC/ASTM Test Method TS-018. The average results were expressed in seconds.

### **2.2.3 Wicking behaviour of cotton, modal and cotton / modal blend fabrics**

The strip test<sup>14, 15</sup> was employed to measure the capillary action of textile fabrics (woven and knitted) such as cotton (100%), modal (100%) and cotton / modal (50 : 50). A sample (20 cm X 2.5 cm) was suspended vertically with its lower end immersed in a reservoir of distilled water for 10 min, and the height attained by the water in the fabric above water level in the reservoir was noted in centimeter.

### **2.2.4 Dyeing of cotton, modal and cotton / modal blend fabrics**

The dyeability of fabrics (woven and knitted) such as cotton (100%), modal (100%) and cotton / modal (50 : 50) 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<sup>16, 12</sup>. The dyed samples were washed, soaped and dried.

Colour intensities of the dyed fabrics were measured using spectrophotometer (model: Premier colour scan ss 5000 A) within the range of 400-700 nm. Reflectance values were measured and the relative colour strength

(K/S) was calculated using Kubelka Monk equation. (K/S) defines a relationship between spectral reflectance (R) of sample and its absorption (K) and scattering (S) characteristics.  $K/S = \{(1-R)^2/2R\}$ <sup>16, 17, 18, 19, 20</sup>.

### **2.2.5 FTIR analysis for the natural dye kum kum**

Fourier Transfer Infra Red (FTIR) spectrophotometer (Shimadzu, Japan) was used to analyze the functional group of the natural dye sample kum kum. 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<sup>21</sup>.

### **2.2.6 Antibacterial property of cotton, modal and cotton / modal blend fabrics**

The antibacterial activity on the fabric samples was assessed qualitatively according to the AATCC test method 147-2004 by the parallel streak method<sup>22</sup>.

## **3. RESULTS AND DISCUSSION**

### **3.1 Absorbency of cotton, modal and cotton / modal woven and knitted fabric**

The data of absorbency of cotton, modal and cotton / modal woven and knitted fabrics dyed with kum kum, indigo, bar berry, reactive dye (H), reactive dye (M) and sulphur dye is given in Table 1. It is seen from this table that the overall absorbency exhibited by woven fabric (cotton, modal and cotton / modal) is more than that of knitted fabric (cotton, modal and cotton / modal). The absorbency is maximum for cotton followed by cotton / modal and modal fabrics respectively both in the case of woven and knitted fabrics. The reactive dyed (H) materials (cotton, modal and cotton / modal) show the maximum absorbency followed by reactive dyed (M), kum kum dyed, bar berry dyed, indigo dyed, and sulphur dyed textiles. This trend is common in both the woven and knitted textile (cotton, modal and cotton / modal) materials. The maximum absorbency

of cotton is exhibited by its purity and arrangement of cellulose polymer in the total fibre content. The textile materials (cotton, modal, cotton / modal (50 : 50 blend) fabric (woven and knitted) dyed with soluble dyes (both natural (kum kum and bar berry) and synthetic (Reactive H & M) ) show more absorbency than that of insoluble dyes (Indigo and Sulphur).

**Table 1 : Absorbency of cotton, modal and cotton / modal woven and knitted fabric**

S. No.	Dye Application	Drop Absorbency (seconds)					
		Woven Materials			Knitted Materials		
		Cotton	Modal	Cotton / Modal	Cotton	Modal	Cotton / Modal
1	Kum kum	10	14	12	12	16	15
2	Indigo	12	19	15	15	22	18
3	Bar berry	11	15	12	13	18	16
4	Reactive Dye (H)	9	12	10	11	14	13
5	Reactive Dye (M)	9	13	11	12	16	15
6	Sulphur Dye	14	20	17	16	24	19

### 3.2 Wicking of cotton, modal and cotton / modal woven and knitted fabric

The data of wicking behaviour of cotton, modal and cotton / modal (woven and knitted) fabrics dyed with kum kum, indigo, bar berry, reactive dye (H), reactive dye (M) and sulphur dye are given in Table 2. From Table 2, it is clear that the wicking behaviour of all the samples is good, however woven fabrics show some edge over the knitted fabrics. The wicking behaviour shown by cotton is maximum followed by cotton / modal and modal fabrics respectively both in the case of woven and knitted fabrics. The reactive dyed (H) materials (cotton, modal and cotton / modal) show the maximum wicking followed by

reactive dyed (M), kum kum dyed, bar berry dyed, indigo dyed, and sulphur dyed textiles. This trend is common in both the woven and knitted textile (cotton, modal and cotton / modal) materials. The wicking character is more for the textile materials (cotton, modal, cotton / modal (50 : 50 blend) fabric (woven and knitted)) dyed with soluble dyes (both natural (kum kum and bar berry) and synthetic (Reactive H & M) ) than that of insoluble dyes (Indigo and Sulphur).

**Table 2: Wicking of cotton, modal and cotton / modal woven and knitted fabric**

S. No.	Dye Application	Wicking (cm)					
		Woven Materials			Knitted Materials		
		Cotton	Modal	Cotton / Modal	Cotton	Modal	Cotton / Modal
1	Kum kum	16	13	15	13	11	12
2	Indigo	15	12	13	12	10	11
3	Bar berry	16	13	14	14	11	12
4	Reactive Dye (H)	19	14	17	16	12	14
5	Reactive Dye (M)	17	13	16	15	11	14
6	Sulphur Dye	14	11	12	11	09	10

### **3.3 Colorimetric data of kum kum, indigo, bar berry, reactive dyes, and sulphur dye on cotton, modal and cotton / modal (woven and knitted) fabrics**

The calorimetric data of kum kum, indigo, bar berry, reactive dye (H), reactive dye (M) and sulphur dye applied on cotton, modal and cotton / modal (woven and knitted) fabrics are presented in Tables 3a, 3b and 3c respectively. From the Table 3a, it is seen that the cotton fabrics (woven and knitted) dyed with kum kum, indigo, bar berry, reactive dye (H), reactive dye (M) and sulphur dye show good calorimetric data. The average k/s value for the woven cotton

fabric dyed with kum kum, indigo, bar berry, reactive dye (H), reactive dye (M) and sulphur dye is around 14.66 whereas this value is less for knitted cotton fabric (around 14.1). The k/s value for reactive dyes (H & M) is around 14.85 followed by 14.65 (sulphur dye), 14.60 (Indigo), 14.54 (bar berry), and 14.50 (kum kum) respectively. The knitted fabric (cotton) also follows the same trend of calorimetric data, such as, for reactive dyes (H & M) around 14.36 followed by 14.21 (sulphur dye), 14.01 (Indigo), 13.95 (bar berry), and 13.70 (kum kum) respectively. In Table 3b and 3c the calorimetric data of kum kum, indigo, bar berry, reactive dyes, and sulphur dye present on modal fabric (woven and knitted) and cotton / modal (50 : 50) fabric (woven and knitted) are shown. The calorimetric data obtained on modal (table 3b) fabric and cotton / modal (Table 3c) fabric is correspondingly less than that obtained on cotton fabric (table 3a). However, the trend obtained on cotton fabric (woven and knitted) is also followed for modal (woven and knitted) and cotton / modal (woven and knitted) fabric respectively. The k/s value around 12 and more than 12 is considered to be good colour strength. Hence, the calorimetric data (Tables 3a, 3b and 3c respectively) on cotton, modal and cotton / modal (50 : 50) fabrics (woven and knitted) dyed using kum kum, indigo, bar berry, reactive dye (H), reactive dye (M) and sulphur dye are in the accepted value.

**Table 3a : Colorimetric data of kum kum, indigo, bar berry, reactive dyes, and sulphur dye on woven and knitted cotton fabric**

S. No.	Dyes	Colorimetric data of dyed Modal											
		Woven Fabric						Knitted Fabric					
		L*	a*	b*	C	h°	K/S	L*	a*	b*	C	h°	K/S
1	Kum kum	31.04	-5.98	-15.52	22.02	255	14.50	27.71	-5.84	-15.95	23.51	251	13.70
2	Indigo	37.91	-6.15	-15.30	21.62	251	14.60	26.20	-6.06	-14.41	23.10	262	14.01
3	Bar berry	32.06	-5.30	-15.08	21.59	251	14.54	29.54	-5.96	-14.24	22.95	262	13.95
4	Reactive Dye (H)	35.26	-4.32	-15.15	23.54	241	14.87	36.50	-6.95	-16.62	22.87	253	14.42
5	Reactive Dye (M)	27.42	-5.30	-14.87	22.14	265	14.84	36.80	-4.65	-16.84	23.01	256	14.30
6	Sulphur Dye	33.32	-4.62	-15.18	23.95	268	14.65	28.65	-4.75	-16.16	23.54	246	14.21



**Table 3b : Colorimetric data of kum kum, indigo, bar berry, reactive dyes, and sulphur dye on woven and knitted modal fabric**

S. No.	Colorimetric data of dyed cotton												
	Dyes	Woven Fabric						Knitted Fabric					
		L*	a*	b*	C	h°	K/S	L*	a*	b*	C	h°	K/S
1	Kum kum	34.41	-5.14	-14.05	22.26	255	13.15	36.02	-5.95	-15.98	23.98	248	12.98
2	Indigo	26.12	-5.58	-14.98	22.23	244	14.30	34.32	-5.48	-16.32	22.87	256	13.45
3	Bar berry	26.87	-6.74	-15.95	22.41	260	13.41	34.84	-6.79	-14.58	21.85	241	13.32
4	Reactive Dye (H)	25.95	-5.47	-15.98	23.90	259	14.95	33.32	-5.30	-14.52	23.52	248	14.25
5	Reactive dye (M)	35.54	-5.84	-14.74	22.56	258	14.41	24.62	-5.62	-15.74	22.98	265	13.98
6	Sulphur Dye	35.74	-5.85	-15.30	22.25	256	14.32	34.63	-5.32	-16.65	22.56	256	13.65

**Table 3c : Colorimetric data of kum kum, indigo, bar berry, reactive dyes, and sulphur dye on woven and knitted cotton / modal fabric**

S. No.	Colorimetric data of dyed Cotton / Modal												
	Dyes	Woven Fabric						Knitted Fabric					
		L*	a*	b*	C	h°	K/S	L*	a*	b*	C	h°	K/S
1	Kum kum	33.96	-6.75	-14.30	21.48	251	12.51	33.15	-4.74	-16.98	23.20	256	12.25
2	Indigo	36.45	-5.62	-15.03	23.15	253	13.24	35.51	-6.54	-16.59	21.03	259	12.98
3	Bar berry	36.05	-4.95	-15.04	22.48	250	12.75	27.51	-6.58	-15.95	22.32	266	12.65
4	Reactive Dye (H)	32.96	-5.05	-16.51	21.01	240	13.95	27.60	-5.50	-15.62	23.84	249	13.62
5	Reactive Dye (M)	32.87	-5.96	-16.62	21.60	250	13.84	28.80	-5.52	-15.4	21.32	260	13.54
6	Sulphur Dye	36.36	-5.52	-15.74	22.74	267	13.60	35.30	-4.80	-15.01	22.05	265	13.32

### 3.4 FTIR analysis of kum kum dye extract

The FTIR spectrum of kum kum dye extract is shown in Figure 1. From this figure it is evident that the groups such as hydroxyl group - OH (3500), carbonyl group >C=O (2000) and ether group -O- (900) are present in the kum

kum dye extract. These data indicate that there is a presence of chromophore (>C=O) and auxochrome (-OH) in the natural (organic) dye (kum kum) extract which is responsible for releasing colours and fixing them on the textile fibre substrates.

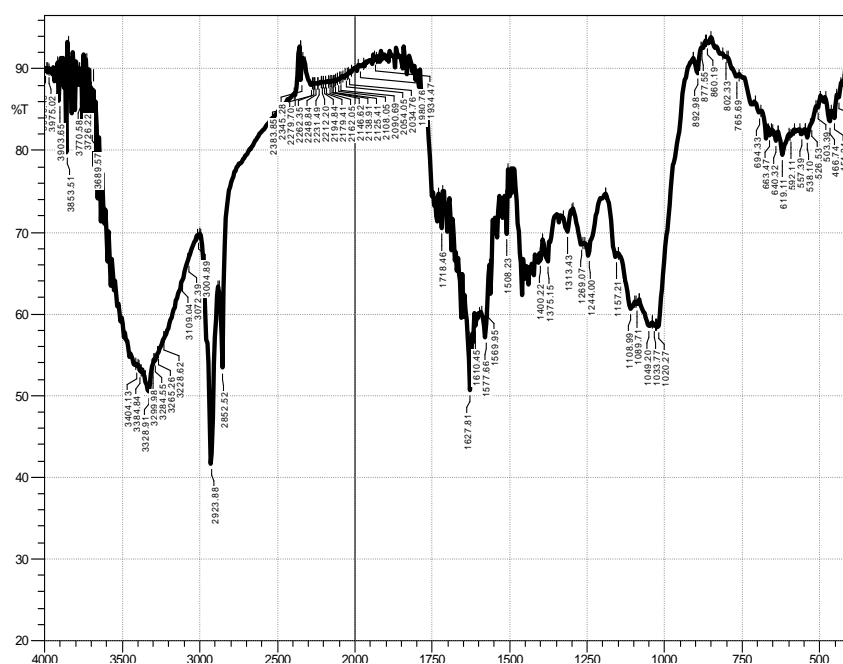


Figure 1 : FTIR spectrum of kum kum dye extract

### 3.5 Antimicrobial property of kum kum, indigo, bar berry, reactive dyes, and sulphur dye on cotton, modal and cotton / modal (woven and knitted) fabrics

The data of antibacterial property of cotton, modal and cotton / modal (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 4a and 4b respectively. 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*. In general, the modal fabric shows a higher zone of inhibition (both by *Staphylococcus aureus* and *Escherichia coli*) followed by cotton / modal (50 : 50) 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 cotton, modal and cotton / modal (50 : 50) fabrics (woven and knitted) exhibited by *staphylococcus aureus* and *escherichia coli*.

**Table 4a : Qualitative antibacterial assessment of dyed fabric against *Escherichia aureus***

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

**Table 4b : Qualitative antibacterial assessment of dyed fabric against *Staphylococcus coli***

S. No.	Textile fabric sample		Antibacterial activity (Zone of Bacteriostasis – mm) <i>Escherichia coli</i>					
			Fabrics dyed with natural dyes			Fabrics dyed with synthetic dyes		
			Kum kum	Indigo	Bar berry	Hot reactive	Cold reactive	Sulphur
1	Woven	Cotton	27	30	28	34	33	32
2		Modal	30	35	32	43	40	38
3		Cotton / modal	28	31	30	38	36	35
4	Knitted	Cotton	25	29	26	32	30	30
5		Modal	28	34	30	40	38	37
6		Cotton / modal	26	30	29	36	34	330

#### 4. CONCLUSIONS

From this research work the following conclusions are arrived;

1. The absorbency and wicking characters of modal fabric and cotton / modal (50 : 50 blend) fabric (woven and knitted) are good similar to that of cotton fabric.
2. The colorimetric values of natural dyed (kum kum, bar berry and indigo) and synthetic dyed (reactive (H & M), and sulphur) modal and cotton / modal (50 : 50 blend) fabric are good and with the expected value suitable for textiles and garments. This is no way inferior to that obtained on cotton fabric.
3. FTIR analysis reveals the presence of chromophore and auxochrome confirm the dye characteristics of natural dye (kum kum).

4. The antimicrobial character of modal fabric in its original form and its blend with cotton dyed with both natural dye (kum kum, bar berry, and indigo) and synthetic dye (reactive (H & M) and sulphur) is good when compared with the corresponding cotton fabric.

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