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Research Article

A STUDY OF OVERALL MOISTURE MANAGEMENT CAPABILITY OF PLASMA TREATED BAMBOO/COTTON BLENDED FABRICS FOR MEDICAL APPLICATIONS

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ABSTRACT

This paper reports the suitability of bamboo/cotton blended woven fabrics for hospital beddings following plasma treatment. A series of woven bamboo/cotton blended fabric comprising 100% bamboo 75/25, bamboo/cotton, 50/50 bamboo/cotton, 25/75 bamboo/cotton and 100% cotton fabric was produced and plasma treatment was applied on them. Both bleached and plasma treated fabrics were characterised by overall moisture management capacity (OMMC). The results show that bamboo fabrics have the highest OMMC while cotton shows the lower OMMC, The blend consisting of 75/25 blend both in plain and twill weaves shows the highest OMMC which makes them suitable for hospital beddings. With the exception of 100% cotton fabric, plasma treatment has led to a drop in OMMC indicating that the fabrics have become water repellent. These can be used in medical applications as surgical gowns and in gauze bandages.

Keywords: Bamboo, Blended fabrics, OMMC and plasma treatment.

INTRODUCTION

During convalescing, the patient requires sound sleep and doubtless the bedding plays an important role. An important feature of fabric made form bamboo fibre is that natural antibacterial elements (bio agent "bamboo Kun") resists bacteria. Beddings containing bamboo can absorb and evaporate human sweat in a split second just like breathing and make the patients more comfortable since the fabric never sticks to skin even in hot summer. Also, anti ultra violet nature of bamboo fibres makes it eminently suitable for summer clothing. These are most desirable for pregnant ladies and kids. Despite some disadvantages of bamboo fibres such as low strength, it has wide scope to be used for sanitary napkins, masks, mattress and food packages. Also, bandages, surgical clothes, gauze bandage and nurse wear will benefit from bamboo fibre. They can be used for kids having drooling problems. An excellent account of bamboo fabric in comparison to fabrics made of cotton and viscose is given by Mishra et al. (1).

Plasma treatment has become an important technological process which is meant for improving the performance of textiles. Although bamboo fibre is endowed with antimicrobial effect, it is likely that the effect may be lost during processing. There is a plethora of literature available on plasma treatment of textile materials. There are two excellent books published by Shishoo (2) and Kan et al (3) on plasma technology. The general effects of plasma treatment on textile fibres, yarns and fabrics have been discussed. Among the many significant contributions made by the Hong Kong polytechnic, Hong Kong, the OMMC test developed by Hu etal. (4) has been found to be a useful instrument for undertaking studies on moisture management of textile materials. Undoubtedly, Hu's piece de resistance is the MMT.

In 1953 Hearle (5) published his celebrated paper on the electrical resistance of textile materials and demonstrated the effect of relative humidity on it. Taking this idea from Hearle's work, Shirley Institute developed an instrument for measuring moisture based on the electrical resistance of textile materials. The electrical resistance of textiles is usually very large when placed in a closed circuit. Thus no electric current can be detected However, when a fabric containing moisture is placed, the resistance will reduce to a very large extent and this concept has been brought to fruition. This principle is used to measure moisture content of a textile fabric. Water content changes with reference to time on the fabric's top and bottom surfaces. This indicates that most of the liquid introduced onto the top surface of fabric transfers quickly to the bottom surface. Thus Hu's instrument was derived from the fusion on electrical resistance of Hearle's work.

The various components of MMT are described below;

1. Wetting time WT_t (top surface) and WT_b (bottom surface) (seconds) WT_t and WT_b are the time periods in which the top and bottom surfaces of the fabric just start to be wetted respectively, after the test commences, defined as the time in seconds when the slopes of total water contents on the top and bottom surface (i.e. U_t and U_b) become greater than tan (15°) Wetting times can be compared with the absorbency drop test specified in AATCC 79.

2. Maximum absorption rates MAR_t and MAR_b (%/sec) are defined as.

MAR_t = Max (Slope (U_t))……….. 1

$MAR_t = 0$ if $MAR_t < 0$, and………2

MAR_b = Max (Slope (U_b))………..3

$MAR_b = 0$ if $MAR_b < 0$ 4

3. Maximum wetted radius MWR_t and MWR_b (mm) are maximum wetted ring radii at the top and bottom surfaces respectively, where the slopes of water content (M_{ti} or M_{bi}) become greater than tan (15°) for the top and bottom surfaces to reach the maximum wetted radius, defined as

$$SS_t = \frac{MWR_t}{t_{wrt}} \quad \text{............5}$$

$$SS_b = \frac{MWR_b}{t_{wrb}} \quad \text{................6}$$

Where t_{wrt} and t_{wrb} are the times to reach to the maximum wetted rings on the top and bottom surfaces, respectively.

4. Cumulative one-way transport capacity OWTC: OWTC is the difference in the cumulative moisture content between the two surfaces of the fabric in the unit testing time period.

$$OWTC = \frac{\int U_b - \int U_t}{T} \quad \text{...............7}$$

Where T is the total testing time. U_b is greater than U_t because the bottom layer absorbs more moisture. This is the most important parameter which affects OMMC and defined as

$$\frac{Area(U_{bottom}) - Area(U_{top})}{TotalTestingTime} \quad \text{…....8}$$

5. Overall moisture management capacity (OMMC) is defined as

OMMC = C_1 MAR_b + C_2 OWTC + C_3 SS_b …………………….9

Where C_1, C_2 and C_3 are the weights of the indexes of the absorption rate (MAR_b) the one way transport capacity (OWTC) and the spreading/drying rate (SS_b). Here C_1 0.25, C_2 = 0.5 and C_3 = 0.25. That these can be adjusted has been pointed out.

The moisture management tester (MMT) was developed to evaluate the horizontal wicking ability of a fabric using the electrical impedance concept. The device consists of two (upper and lower) series of concentric wire rings, which measure the electrical resistance of a disc sample of different radii. Springs, which are provided, ensure a homogeneous contact between the sensor and the fabric. The distance between the rings gives the spatial resolution. The test is performed by adding a drop of water which simulates sweat and wicking occurs radially as in a spot test. There are nine parameters, namely, wetting time top, wetting time bottom, top absorption rate, bottom absorption rate, maximum wetted radius top, maximum wetted radius bottom, spreading speed top, spreading speed bottom one way transport index which are measured and by combining them an overall moisture management capacity (OMCC) is obtained. A PC which is connected to the instrument and controlled by special software provides the data. It is indeed remarkable that ever since the apparatus was developed by Hu etal (4), a large number of papers have been published by a number of research workers. The effect of fibre, yarn, fabrics and plasma treatment and cover factor of knitted fabrics has been extensively studied on OMMC. The literature survey indicated (6-16) that all the studies on effect of plasma treatment were conducted on single component fabrics and a self contained study which comprises several blends of bamboo and cotton and with plain and twill weaves is warranted. In order to fill this gap in literature in this study, the overall moisture management capacity of bamboo/cotton blended woven fabrics produced with plain and twill weaves and treated with plasma has been investigated before and after plasma treatment. The purpose of this study is to recommend the appropriate blend for hospital beddings in the hospitals. This will aid fibre producers and garment manufactures. The present study was concerned mainly with the evaluation of a series of bamboo cotton woven fabrics using the tester developed by Hu etal. (2005) and which has been accepted by the American Association of Textile Chemists and Colourists (AATCC) as a test method. Also, the objective of the study is to develop an innovative product for medical textiles by plasma treatment.

MATERIALS AND METHODS

Bamboo and cotton fibers were used for producing blends containing 75B/25C, 50B/50C and 25/75 bamboo. Besides these, 100% bamboo and 100% cotton yarns were produced. The properties of the fibre used for the production of yarns are given in Table 1.

Table 1: Details of the fibre properties used in the studies

Fibers	Fibre length(mm)	Tenacity (g/tex)	Elongation (%)	Fibre Uniformity (%)	Moisture Content (%)
Cotton	27.7	36.1	5.7	81.5	7.6
Bamboo	36	35.2	15	91.4	11.42

Yarns of 40s Ne in each blend, 100% cotton and 100% bamboo were produced following the procedures used in the industry.

METHODS

Woven fabrics production

Fabrics were woven with plain and twill fabrics on miniature loom and details of these are given in Table 2.

Table 2: Geometrical properties of fabrics

	Fabric Sett		Thickness (mm)		Areal Density		Porosity (%)	
Blending Ratio	**Warp (Ends/cm)**	**Weft (Picks/cm)**	**Plain weave**	**Twill weave**	**Plain weave**	**Twill weave**	**Plain weave**	**Twill weave**
Bamboo 100%	32	30	0.31	0.39	110	115	76	80
Bamboo/Cotton 75/25	32	30	0.39	0.45	115	118	81	83
Bamboo/Cotton 50/50	32	30	0.38	0.4	120	122	79	81
Bamboo/Cotton 25/75	32	30	0.38	0.4	122	124	76	79
Cotton 100%	32	30	0.33	0.42	124	126	75	80

Plasma treatment

A Diener vacuum plasma device was used in which the distance between the electrodes was 0.2cm. The samples were placed between the electrodes. In all the cases, an uniform glow discharge plasma system owing operating under atmospheric conditions with oxygen was used as a processing gas under a power of 400W. The fabric was prepared in dimensions of 60mm*120 mm for plasma treatment given for 10 minutes. Owing to the interactions between air and the activated surface, plasma treated fabric was subjected to conditioning for 24h at 25° C at a relative humidity of 65%.

Moisture Management Properties

Moisture management tester (MMI) (SDL Atlas, Hong Kong) (AATCC test method 195-2009) was used for testing the liquid moisture transfer properties of the fabrics. The electrical resistance of fabric changes when exposed to moisture depending on the liquid components and water content in the fabric. The liquid components are fixed since same amount of test solution (simulating sweat) is dropped on the top (next to skin) surface of fabric. Thus the water content in fabric determines the measured electrical resistance. This principle is employed in MMT to obtain moisture management indices for top and bottom layers of fabric, Onto each specimen top (next to spin) surface, 0.15g of test solution simulating sweat was dropped automatically by the instrument. A computer records the resistance changes between each couple of proximate metal rings individually at top and bottom sensors. The test solution will transfer in three directions from fabrics top surface (next to spin) spreading outward on the top surface of the fabric, transferring through the fabric from the top to the bottom surface of fabrics. The implications of the nine parameters are well discussed by Hu et al. (2005).

The larger the value of OMMC, the higher the overall moisture management ability of the fabric. The same comments hold good for OWTI parameter.

RESULTS AND DISCUSION

Tables 3-6 present data on moisture management of untreated and treated fabrics constructed from various blends. It is apparent that in plain woven fabrics the fabric containing 25% bamboo and 75% cotton exhibits higher OMMC value and all cotton fabrics show the lowest value. In respect of twill weave, the fabric containing 75% bamboo and 25% cotton displays highest OMCC. The all cotton fabric shows the lowest value. In a few cases, OMCC values show a decrease with respect to twill weaves fabrics in comparison to plain weave in untreated states. There is no trend between blend composition and OMMC which is contradictory to the findings of Prakash et al. These authors have reported that 100% cotton is characterised by higher OMMC in comparison to 100% bamboo. Also, a progressive reduction in OMCC with increase in bamboo content is reported which is not noticed in this study.

With the exception of 100% cotton, it is noticed that there is a drop in OMMC following plasma treatment in plain woven fabrics. Fabric containing 100% cotton with plain weave has a higher OWTC (one-way transport capacity) and OMMC (Overall moisture management capacity). This demonstrates that liquid sweat can be easily and quickly transferred from next to skin to the outer surface to keep the skin dry. Wetting times are higher for both the cotton fabrics containing 100% cotton having plain and twill weave in bleached state. These are drastically reduced in fabrics following plasma treatment, Studies carried out on the wickability of cotton fabrics show poor wickability. Generally it is noticed that OWTC value shows a fall in plasma treated samples Figures 1-12 show these changes Fabrics which possess low OWTC values indicate that the liquid) sweat) can transfer from the surface next to the skin to the opposite surface and spread quickly on the fabric bottom surface with a large wetted area where it evaporates into the environment. These dry very fast, With the exception of 100% cotton, plasma treatment has led to a drop in OMCC to the extent of 10%. These fabrics are environmentally suitable for surgical wear, Also these can be used for wound healing where water repellency is required.

Differences between the top and bottom parameters are given in Tables 7 and 8. With regard to wetting time, there is a significant reduction following plasma treatment for plain woven fabrics. This is found to be similar for twill woven fabric also, Absorption rates are negative in all the cases showing that bottom layer show an increase in comparison to top layer. An interesting observation is a larger difference in wetting top is noticed for twill woven fabric in comparison to plain woven fabric. In the case of 100% cotton fabrics, absorption rate is higher for plasma treated fabrics in both the cases. Spreading speeds show a significant reduction following plasma treatment in respect of 100% cotton fabric in both the cases. Cotton has a relatively large spreading rate in both the weaves, following plasma treatment, indicating that the liquid (sweat) cannot diffuse easily from the next to-skin surface to the opposite side and will accumulate on the top surface of fabric. In all the cases an increase in spreading speed is noticed. In cotton spreading speed increases both plain and twill weaves. The correlation coefficients between OWTC and OMMC are – 0.973, 0.469,0.986 and 0.885 respectively. Higher values of OMMC are due to higher top absorption rate and bottom spreading speed, poor liquid moisture management.

Table 3: Mean values of MMT test result for untreated fabrics (Plain Weave)

Sl no	BLENDS	Wetting time (seconds)		Absorption Rate (%/sec)		Maximum wetted radius (mm)		Spreading speed (mm/sec)		One way Transport Index (%)	OMMC
		Top Layer	Bottom Layer	Top Layer	Bottom Layer	Top Layer	Bottom Layer	Top Layer	Bottom Layer		
1	BAMBOO 100%	2.901	2.901	47.780	69.1028	25	24	4.262	4.1914	207.490	0.7003
2	B/C 75:25	3.107	3.257	50.465	73.079	25	25	4.137	4.0949	221.235	0.7229
3	B/C 50:50	3.107	3.257	50.465	73.081	25	25	4.137	4.0951	221.236	0.7231
4	B/C 25:75	3.407	3.482	46.85	77.1972	26	26	4.767	4.7095	212.822	0.7287
5	COTTON 100%	13.122	11.905	16.395	25.6194	28	29	1.908	1.8792	350.494	0.5616

Table 4: Mean values of MMT test result for untreated fabrics (Twill Weave)

Sl no	BLENDS	Wetting time (seconds)		Absorption Rate (%/sec)		Maximum wetted radius (mm)		Spreading speed (mm/sec)		One way Transport Index (%)	OMMC
		Top Layer	Bottom Layer	Top Layer	Bottom Layer	Top Layer	Bottom Layer	Top Layer	Bottom Layer		
1	BAMBOO 100%	2.733	2.714	44.610	70.335	22	23	4.113	4.146	181.277	0.672
2	B/C 75:25	4.661	4.68	25.183	67.804	25	25	3.7292	3.668	433.514	0.862
3	B/C 50:50	2.826	2.845	47.483	70.531	25	25	4.4566	4.397	179.797	0.673
4	B/C 25:75	2.508	2.452	41.541	65.386	25	25	5.0228	5.094	206.194	0.688
5	COTTON 100%	12.879	8.854	22.575	35.993	25	24	1.8294	1.625	306.349	0.520

Table 5: Mean values of MMT test result for Plasma treated fabrics (Plain Weave)

Sl no	BLENDS	Wetting time (seconds)		Absorption Rate (%/sec)		Maximum wetted radius (mm)		Spreading speed (mm/sec)		One way Transport Index (%)	OMMC
		Top Layer	Bottom Layer	Top Layer	Bottom Layer	Top Layer	Bottom Layer	Top Layer	Bottom Layer		
1	BAMBOO 100%	2.714	2.752	40.679	65.510	25	25	4.796	4.759	152.786	0.629
2	B/C 75:25	2.209	2.1342	41.175	64.461	30	30	7.172	7.225	99.971	0.567
3	B/C 50:50	2.639	2.6206	44.423	66.728	27	26	5.264	5.192	163.924	0.645
4	B/C 25:75	2.639	2.6394	43.307	69.924	30	29	5.783	5.698	156.415	0.645
5	COTTON 100%	2.508	2.4714	42.306	70.665	30	30	6.633	6.559	158.564	0.650

Table 6: Mean values of MMT test result for Plasma treated fabrics (Twill Weave)

Sl no	BLENDS	Wetting time (seconds)		Absorption Rate (%/sec)		Maximum wetted radius (mm)		Spreading speed (mm/sec)		One way Transport Index (%)	OMMC
		Top Layer	Bottom Layer	Top Layer	Bottom Layer	Top Layer	Bottom Layer	Top Layer	Bottom Layer		
1	BAMBOO 100%	2.227	2.115	39.914	60.797	25	25	5.444	5.605	112.758	0.571
2	B/C 75:25	2.358	2.377	38.590	65.625	30	30	7.0132	7.000	153.669	0.630
3	B/C 50:50	2.695	2.677	41.450	61.555	25	25	5.035	4.991	134.208	0.597
4	B/C 25:75	2.620	2.508	37.441	55.407	29	28	5.909	5.897	132.015	0.578
5	COTTON 100%	2.452	2.433	45.006	65.143	30	30	6.629	6.591	129.177	0.602

Table 7: Differences between the top and bottom layer of plain weave fabrics before and after plasma treatement

		Plain Weave (Before Plasma) Difference between Top and Bottom layer				Plain Weave (After Plasma) Difference between Top and Bottom layer			
Sl no	**BLENDS**	**Wetting time (seconds)**	**Absorption Rate (%/sec)**	**Maximum wetted radius (mm)**	**Spreading speed (mm/sec)**	**Wetting time (seconds)**	**Absorption Rate (%/sec)**	**Maximum wetted radius (mm)**	**Spreading speed (mm/sec)**
1	**BAMBOO 100%**	-0.15	-22	1	0.07	0.04	-25	0	0.04
2	**B/C 75:25**	-0.15	-23	0	0.04	0.07	-23	0	-0.05
3	**B/C 50:50**	-0.08	-23	0	0.04	0.01	-22	1	0.07
4	**B/C 25:75**	1.9	-31	0	0.07	0	-26	1	0.09
5	**COTTON 100%**	1.9	-9	-1	0.63	0.03	-28	0	0.074

Table 8: Differences between the top and bottom layer of twill weave fabrics before and after plasma treatement

		Twill Weave (Before Plasma) Difference between Top and Bottom layer				Twill Weave (After Plasma) Difference between Top and Bottom layer			
Sl no	**BLENDS**	**Wetting time (seconds)**	**Absorption Rate (%/sec)**	**Maximum wetted radius (mm)**	**Spreading speed (mm/sec)**	**Wetting time (seconds)**	**Absorption Rate (%/sec)**	**Maximum wetted radius (mm)**	**Spreading speed (mm/sec)**
1	**BAMBOO 100%**	0.02	-26	-1	-0.03	0.11	-21	0	-0.16
2	**B/C 75:25**	-0.02	-42	0	0.06	-0.02	-27	0	0.01
3	**B/C 50:50**	0.02	-23	0	0.06	0.02	-20	0	0.04
4	**B/C 25:75**	0.05	-24	0	-0.07	0.12	-18	1	0.01
5	**COTTON 100%**	4.02	-13	1	0.21	0.02	-20	0	0.03

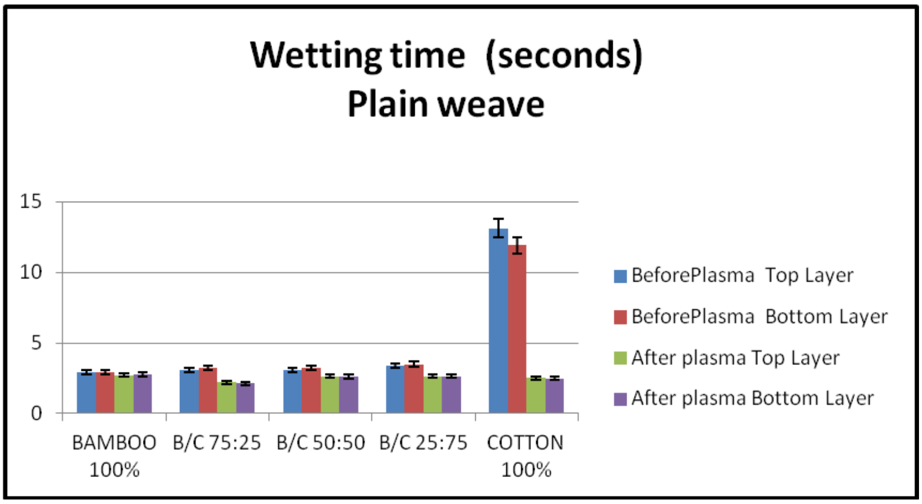

Figure 1:Wetting time top and bottom for plain weave fabric with different blend composition with and without plasma.

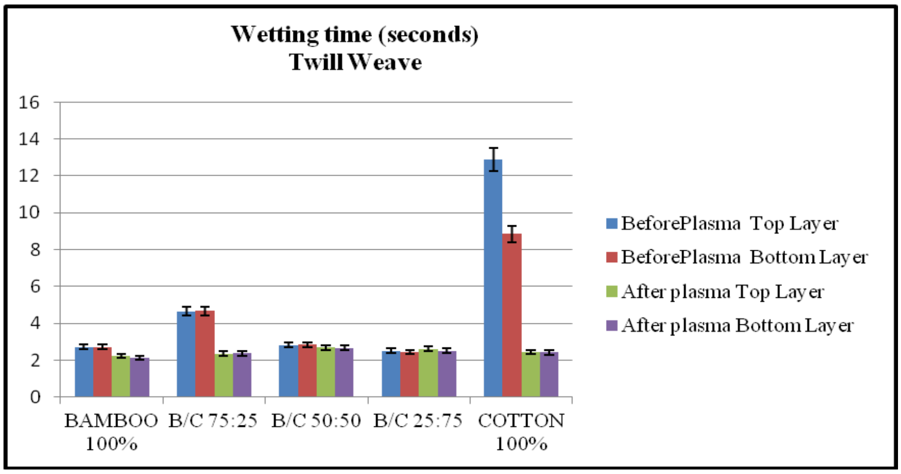

Figure 2:Wetting time top and bottom for Twill weave fabric with different blend composition with and without plasma

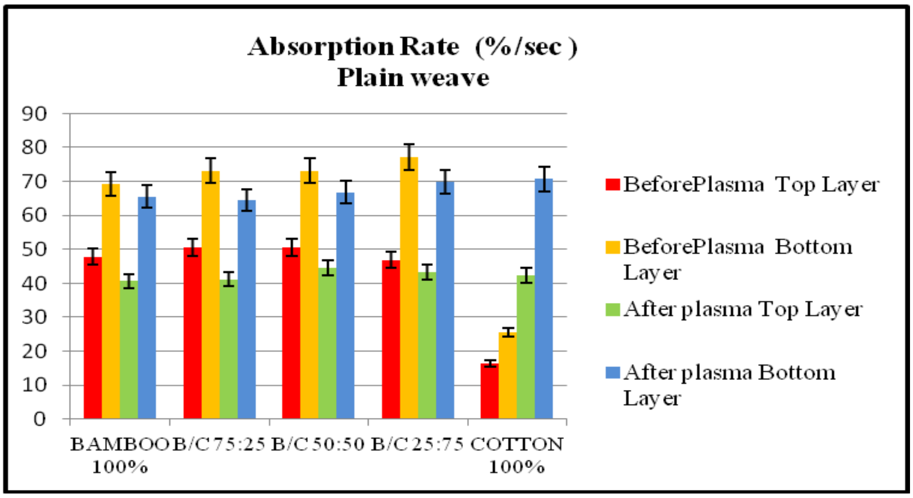

Figure 3: Absorption rate top and bottom for plain weave fabric with different blend composition with and without plasma

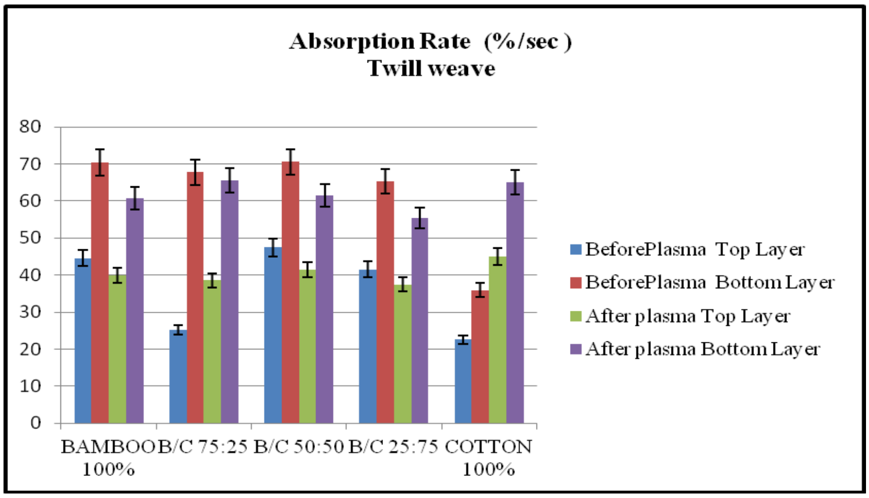

Figure 4: Absorption rate top and bottom for Twill weave fabric with different blend composition with and without plasma.

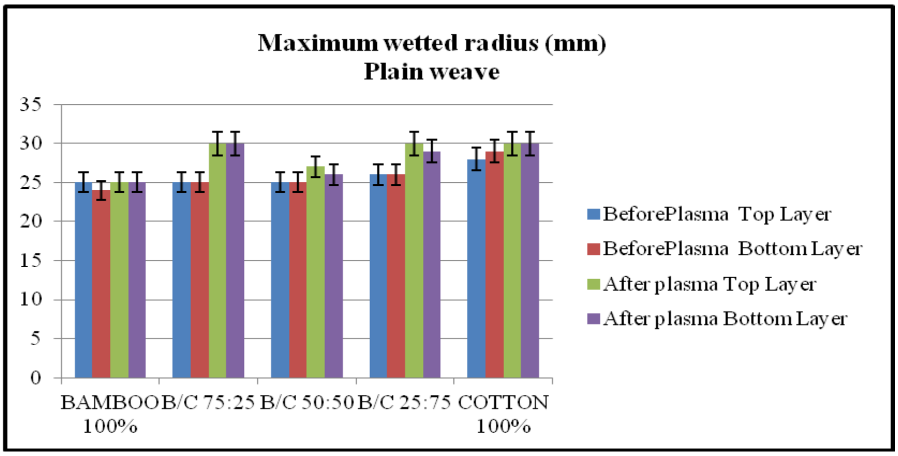

Figure 5: Maximum wetted radius top and bottom for plain weave fabric with different blend composition with and without plasma

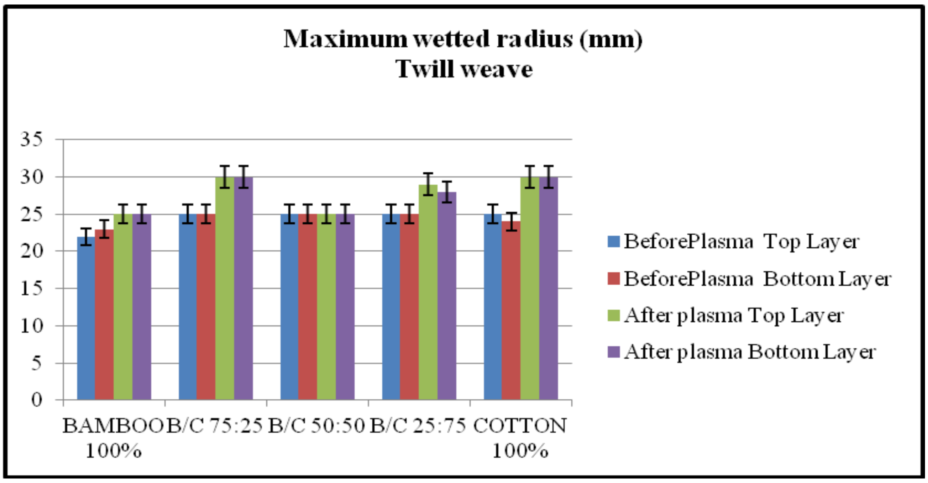

Figure 6: Maximum wetted radius top and bottom for Twill weave fabric with different blend composition with and without plasma

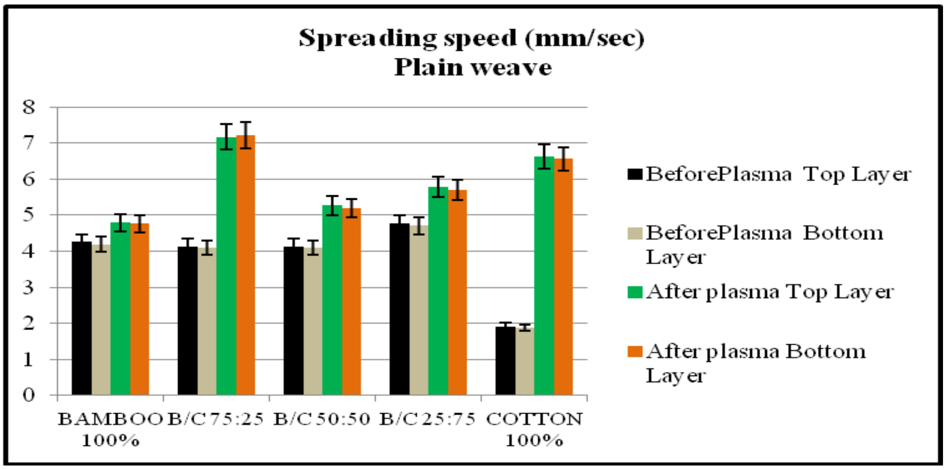

Figure 7: Spreading speed and bottom for plain weave fabric with different blend composition with and without plasma

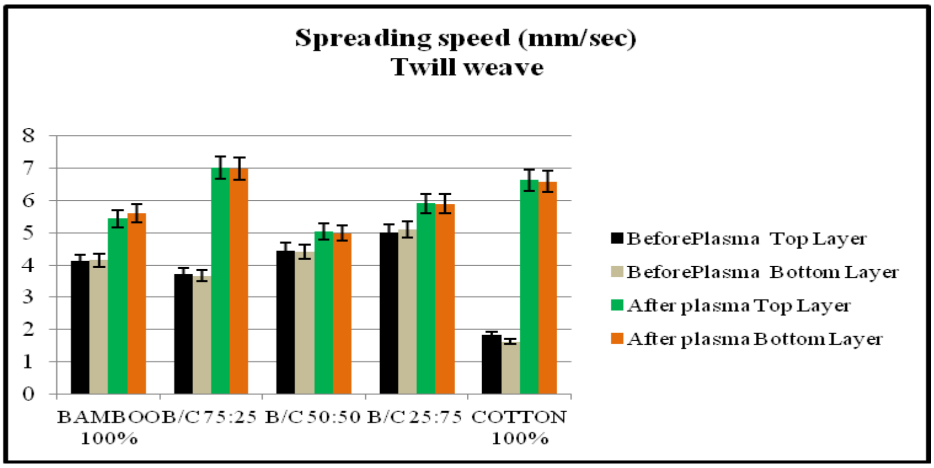

Figure 8: Spreading speed top and bottom for Twill weave fabric with different blend composition with and without plasma

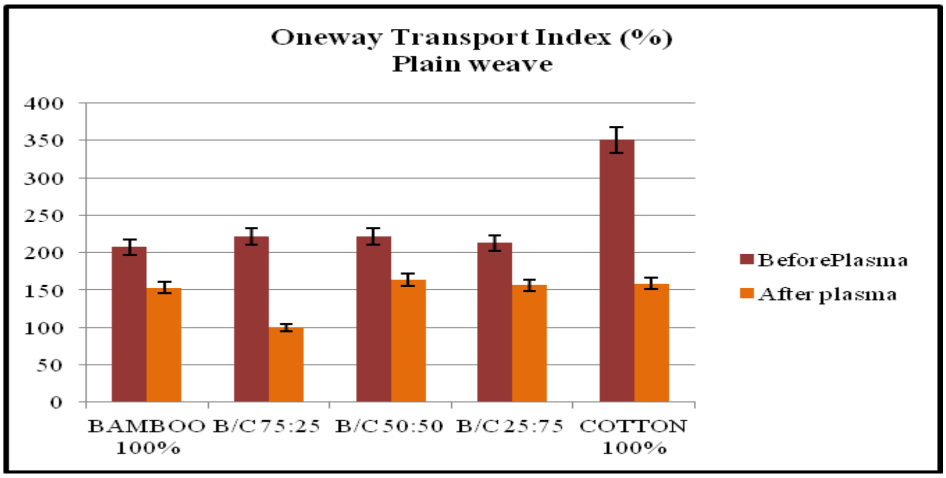

Figure 9: One way transport index for plain weave fabric with different blend composition with and without plasma

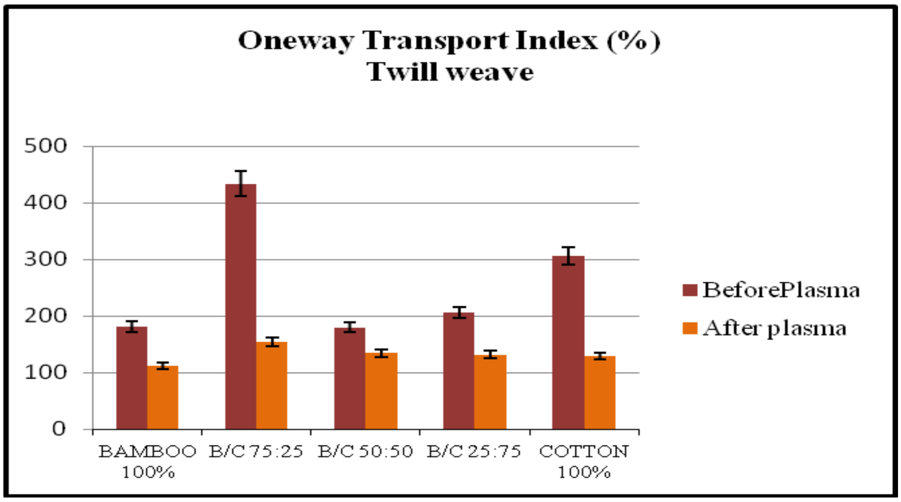

Figure 10: One way transport index for Twill weave fabric with different blend composition with and without plasma

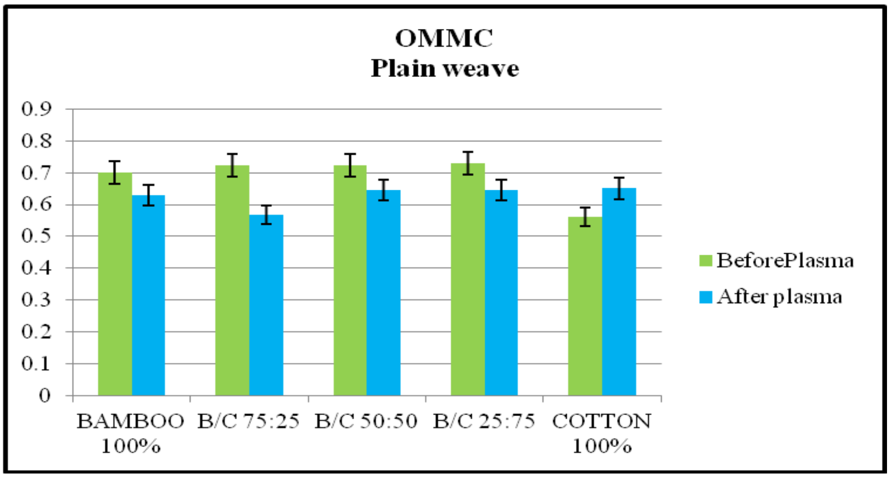

Figure 11: OMMC for plain weave fabric with different blend composition with and without plasma

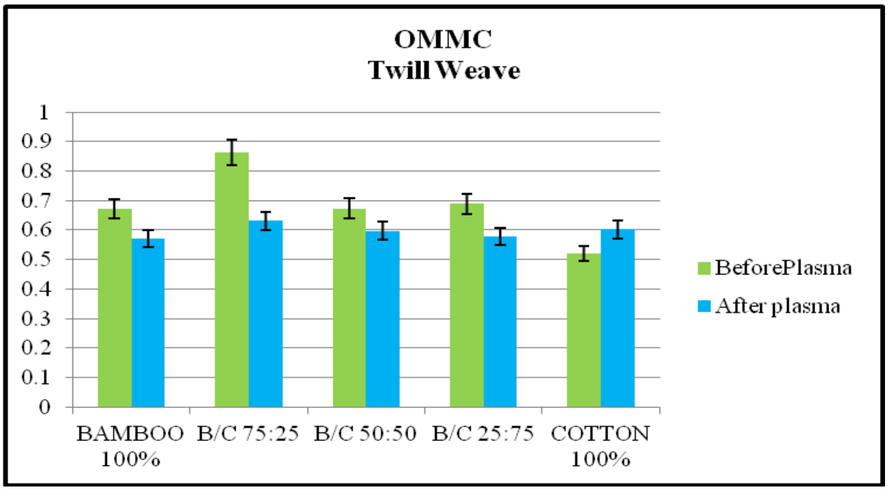

Figure 12: OMMC for Twill weave fabric with different blend composition with and without plasma

CONCLUSION

In respect of 100% Bamboo, 100% Cotton and three different blend ratio, the plasma treatment has resulted in water repellent and bacterial repellent characteristics. Through these studies, it is concluded that100% cottons fabric have better water repellent charactertics. Since for surgical dresses, there two charactertics are essential, the fabric containing bamboo/cotton 50/50 has optimum bacteria repellent charactertics.

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