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Effect of blend ratio and single, double and plated yarn on moisture management properties of bamboo/cotton jersey knitted fabrics

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Effect of bamboo/cotton blend ratio on the moisture management properties of single, double and plated yarn single jersey knitted fabrics has been studied. The moisture management properties of the fabrics are measured by SDL-ATLAS moisture management tester. Absorption rate, wetting time, maximum wetted radius, spreading speeds, one-way transportation capability and overall moisture management capacity are measured and discussed. The results show that the bamboo composition has a significant influence on moisture management properties.

Keywords: Bamboo, Blend ratio, Cotton, Knitted fabrics, Moisture management properties, Plated fabric, Single jersey fabric

1 Introduction

Blending is done to produce a fabric, which is economical by combining the aesthetic comfort properties of the natural fibres with the easy care and strength properties of manmade fibres. Blending also helps to produce a light weight fabric with all desirable characteristics by improving spinning, weaving and finishing efficiency, and the uniformity of product[1-6].

Human body is cooled by evaporation of liquid sweat from the skin surface decreasing body temperature. There are different mechanisms employed in liquid and vapour transfer in textiles. Liquid moisture passage through a textile fabric depends on molecular attraction between fibre and water. This type of interaction is due to the surface tension and capillary pore distribution. Moisture transmission through textile materials has been recognized as an important factor in many applications, such as sportswear, protective wear, textile processing and cleaning, composite manufacturing - resin transfer through the performs in mold filling and in many other areas. Moisture transmission through clothing material plays a very important role in determining its thermal-wet comfort. From the comfort point of view, moisture transmission through textile material both in liquid and vapour forms is equally important. Fabric liquid moisture transport properties in multi-dimensions influence the human perception of moisture sensations and comfort significantly.

Moisture management is one of the key performance criteria in today's apparel industry, which decides the comfort level of that fabric. Wearing garments that transport moisture and evaporate it quickly actually enhance the body ability to cool itself. Moisture management can be defined as the controlled movement of water vapour and liquid water (perspiration) from the surface of the skin to the atmosphere through the fabric. This action prevents perspiration from remaining next to the skin. When body can cool itself more effectively, it actually perspires less. With reduced perspiration, body requires less dehydration, and maintains maximum performance for an extended period of time.

Moisture management in a textile fabric normally focuses on the measurements of dynamic liquid transfer from the inner fabric surface (next-to-skin) to the outer surface, and the water transfer between the two surfaces, including the recording of textile liquid transfer process dynamically and qualitatively[7-9]. Das *et al.*[10] reported an experimental study on the effect of fibre cross sectional shape and fibre diameter on moisture transmission properties of the fabric. They found that the fibre diameter plays an important role in moisture transmission through fabrics. Duru and Candan[11] concluded that fibre type as well as stitch length have a significant influence on liquid transfer characteristic properties of the fabrics. Haghi[12] analysed that if liquid water (sweat) cannot be dissipated quickly, the humidity of the air in the space between the skin and the fabric rises. This increased

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humidity prevents rapid evaporation of liquid water on the skin and gives the body sensation of "heat" that triggers the sweating in the first place. Consequently, the body responds with increased sweating to dissipate excess thermal energy. Thus, a fabric inability to remove liquid water seems to be the major factor causing uncomfortable feelings for the wearer. Zhang *et al.*[13] reported that during sweating, if the clothing moisture transfer rate is slow, the relative and absolute humidity levels of the clothing microclimate will increase, suppressing the evaporation of sweat. This will increase rectal and skin temperatures, resulting in heat stress. It is also important to reduce the degradation of thermal insulation caused by moisture build-up. If the ratio of evaporated sweat and produced sweat is very low, moisture will be accumulated in the inner layer of the fabric system, thus reducing the thermal insulation of clothing and causing unwanted loss in body heat. Therefore, both in hot and cold weather and during normal and high activity levels, moisture transmission through fabrics plays a major role in maintaining the wearer's body at comfort. The present study aims to investigate the liquid moisture management properties of bamboo/ cotton knitted fabrics in relation with different blend ratios.

2 Materials and Methods

Regenerated bamboo fibres, used in the production of the yarn and fabric samples, were obtained from a spinning mill. The fibre properties were: mean length 36 mm, fibre fineness 1.52 dtex, linear density 0.155 tex, moisture regain 11.42%, tenacity 22.84 g/tex and elongation 21.2%.

The Sankar-6 cotton fibre, having the characteristics such as fibre length 27.27 mm, fibre length uniformity ratio 49.58%, fibre fineness 4.52 micrograms/in, fibre maturity 82.53% and trash content 0.19%, was used. Besides preparing 100% bamboo and 100% cotton yarns, blended yarn (50:50 bamboo: cotton) was also prepared for the study (Table 1). It should be emphasized that the bamboo fibres are the cellulose fibres manufactured from bamboo pulp. It was ensured that all the yarns produced had the same mean linear density of 29.53 tex (single), 14.76 tex (plated) and 2/14.76 tex (double).

The above yarns were used to produce single jersey fabrics on Knitmac single jersey knitting machine of the following details: model 2006, gauge 24 GG, diameter 16 inch, speed 27 rpm, feeders 21 and number of needles 1200. The ambient knitting-room atmosphere had a humidity of 65% and a temperature of 30 ± 2°C. All samples were produced with 3 mm loop length. The knitting process was completed with constant machine settings and the samples were kept under in standard atmosphere for 48 h to allow relaxation and conditioning. The samples were scoured at 40 °C for 30 min using synthetic detergent, followed by rinsing for the same time period. After the washing process completed, the samples were dried.

2.1 Testing

For dimensional properties, the number of wales and courses per inch were measured. The mean values of number of wales and courses per inch were determined by taking 10 measurements from different areas of each fabric. Fabric thickness was measured on SDL digital thickness gauge according to ISO 5084 standard. The porosity of the samples was calculated by the method used by Majumdar *et al.*[14]. The physical properties of the fabrics, such as thickness (mm) and weight per unit area (g/m^2) are given in Table 2. The moisture management properties of the bamboo/cotton blended yarn knitted fabrics were evaluated using moisture management tester (MMT) from Atlas, which contained upper and lower concentric moisture sensors, enclosing the knitted sample[7,8]. Based on the signal, a set of indexes was calculated, the descriptions of which are summarized by Hu *et al.*[9]. According to AATCC Test Method

Table 1 — Properties of bamboo/cotton blended yarns

Property	Linear density 29.53 tex			Linear density 14.76 tex		
Blend ratio (bamboo/cotton), %	100/0	50/50	0/100	100/0	50/50	0/100
Diameter, mm	0.238	0.259	0.283	0.185	0.197	0.211
Unevenness, %	7.61	7.14	6.78	9.33	8.63	8.21
Thick /km (+50%)	8	6	4	12	10	9
Thin /km (-50%)	4	3	1	2	1	1
Hairiness, 3mm/km	895	1371	1998	523	833	1247
Neps/km	14	8	7	18	15	13
Tenacity, cN/tex	14.77	13.47	15.88	16.13	14.47	16.93
Elongation, %	11.78	8.37	6.17	9.21	7.01	5.41

195-2009, the indices were graded and converted from value to grade based on a five grade scale.

3 Results and Discussion

Analysis of variance (ANOVA) for effect of various selected parameters on output variables is summarized in Table 3. The mean values of moisture management results of the bamboo/cotton single jersey knit structures are mentioned in Table 3. One way analysis of variance (ANOVA) was performed in order to determine the statistical significance of the effect of blend ratio on moisture management properties. A *P*-value of less than 0.05 indicates that the blend ratio and yarn linear density has statistically significant effect on moisture management property, with 95% confidence level.

3.1 Fabric Physical Properties

It may be observed from the data in Table 2 that the fabric thickness and fabric weight show a decreasing trend with increase in bamboo fibre content for single, double and plated yarn knitted fabrics. These observations are also substantiated by the findings of researchers[1-6], who found that for bamboo/cotton blended yarns with the same linear density, the yarn diameter decreases as the proportion of bamboo fibre increases. This has been attributed to the bamboo blended yarns having lower bending rigidity, since the knitted loops can be compressed easily which reduces the fabrics thickness. However, the thickness of the fabrics reduces and thus the ratio of mass per square meter and thickness increases and therefore porosity increases.

3.2 Moisture Management Properties

The results of moisture management properties of bamboo/cotton fabric samples are summarised in Table

3.3 Effect of Blend Ratio on Wetting Time

The wetting time values of the top and bottom surfaces of the bamboo/cotton fabrics are given in Table 4. Top fabric surface refers to that side of the fabric which comes directly in contact with the skin, wherefrom the perspiration is supposed to be wicked out to the other side. The wetting time changes according to the blend ratio on the top and bottom surfaces. The results indicate that generally wetting time of the bottom surfaces is higher than the top surfaces for all the fabrics as expected. In the scope of this explanation, it can be stated that the wetting time value is related to the water absorbency of the bamboo/cotton blended fabrics. When the results of the thin and thick fabrics from the same type of material are compared, it can be seen that thinner fabrics show quicker wetting time than thicker fabrics, when equal amount of water is used.

3.4 Effect of Blend Ratio on Absorption Rate

The absorption rates of the top and bottom surfaces of the fabrics are given in Table 4. The absorption rate

Table 2 — Physical properties of bamboo/cotton blended yarn knitted fabrics

Yarn linear density, tex	Blend	CPI	WPI	Thickness mm	Mass per square meter g/m^2	Porosity, %
29.53	Cotton	46	34	0.598	221	75.69
	Bamboo: Cotton (50:50)	46	34	0.566	211	67.86
	Bamboo	40	34	0.472	174	53.92
2/14.76	Cotton	46	34	0.592	221	75.44
	Bamboo: Cotton (50:50)	44	34	0.570	217	67.18
	Bamboo	46	36	0.553	212	52.08
14.76 plated	Cotton	48	35	0.666`	249	75.40
	Bamboo: Cotton (50:50)	46	34	0.614	239	66.44
	Bamboo	46	35	0.604	222	54.06

Table 3 — Analysis of variance (ANOVA) of moisture management properties (*P* values)

Significance of factors	WT_t s	WT_b s	AR_t %/s	AR_b %/s	MWR_t mm	MWR_b mm	SS_t mm/s	SS_b mm/ s	R %	OMMC
Yarn linear density	0.014	0.005	0.031	0.036	0.0005	0.001	0.008	0.031	0.010	0.004
Blend ratio	0.001	0.001	0.029	0.056	0.003	0.008	0.011	0.021	0.012	0.003

OMMC – Overall moisture management capacity.

Table 4 — Moisture management test results of bamboo/cotton blended yarn knitted fabrics

Yarn linear density tex	Blend ratio	WT_t s	WT_b s	AR_t %/ s	AR_b % /	MWR_t mm	MWR_b mm	SS_t mm/ s	SS_b mm/ s	R %	OMMC
29.53	Cotton	4.172	4.219	27.555	36.354	24	22	2.8321	2.832	96.491	0.4135
	Bamboo: cotton (50:50)	3.901	4.012	58.947	48.756	22	20	2.7293	2.74	51.099	0.3664
	Bamboo	3.525	3.563	63.585	58.956	20	20	2.5353	2.498	26.828	0.3104
2/14.76	Cotton	4.387	4.463	41.079	48.857	22	20	3.0601	2.901	185.537	0.5373
	Bamboo: cotton (50:50)	4.106	4.237	54.616	50.634	20	18	2.7696	2.764	125.627	0.4193
	Bamboo	3.601	3.844	56.277	56.2771	18	17	2.3812	2.292	87.604	0.4157
14.76 plated	Cotton	4.859	4.509	42.948	40.495	18	18	3.0008	2.88	251.548	0.5358
	Bamboo: cotton (50:50)	4.312	4.381	53.311	48.5507	15	17	2.742	2.392	167.614	0.4562
	Bamboo	3.824	4.101	59.6424	49.644	15	15	2.2801	2.251	90.7582	0.4165

values change according to blend ratio. As explained for the wetting time of the fabrics, when the bamboo content in yarn increases, the thickness of the fabric decreases. Therefore, the absorption rate values of the thinner fabrics become higher. The bottom absorption rates of the fabrics are higher than top surfaces. This indicates that most of the liquid moisture is distributed on the bottom surface of the fabric. The lower absorption rate for bamboo fabric may be attributed to the presence of comparatively larger volume of air entrapped in the larger pores of this structure that hinder the quick absorption of water. This is probably caused by low fabric porosity and comparatively less entrapped air in the structure. The lowest absorption rate is observed for the 29.53 tex cotton:bamboo blend fabric followed by the 2/14.76 tex cotton fabric, while the highest absorption rate is observed for the 14.76 tex plated 100% bamboo fabric. The more the amount of air entrapped, the more effort the water may have to make in the first place to replace the entrapped air. The 29.53 tex 100% bamboo fabric has the highest porosity and the lowest absorption rate, followed by the 2/14.76 tex and 14.76 tex bamboo fabrics. This may be due to lower porosity and comparatively less entrapped air in the structure.

3.5 Effect of Blend Ratio on Maximum Wetted Radius

Maximum wetted radius (MWR) results of all the fabrics are given in Table 4. It can be seen that the maximum wetted radius value decreases for the fabrics made from higher bamboo content. The MWR values are lower in bamboo blended fabrics, as compared with the 100% bamboo fabric. Because of the hydrophilic character of both cotton and bamboo fibres, some of the test liquid is absorbed by the fibres and penetrates into the fibre structure, which results in lower moisture spreading along the fabric. In the test equipment the top surface of the fabric is designed in such a way that the inner surface will be in touch with the human skin. Since the bamboo fabrics have the lowest top wetted radius value which indicates its good moisture transport property, it will give a dry feeling to the wearer.

3.6 Effect of Blend Ratio on Water Spreading Speed

The water spreading speed test results are given in Table 4. It can be clearly seen that the higher the bamboo fibre ratio, the higher is the spreading speed. When the fabrics are thinner, the wetting time decreases as mentioned earlier and consequently the spreading speed for wetting of the thicker fabric is higher as compared to the thinner fabric. This is probably due to the low porosity value of bamboo blended fabrics.

3.7 Effect of Blend Ratio on Fabric's AOTI and OMMC

Accumulative one way transport index (AOTI) is the difference in the accumulative moisture content between the two surfaces of the fabric. AOTI reflects the one-way liquid transport capacity from the top surface (inner next to the skin) to the bottom (outer) surface of the fabric. The relationship between blend ratio and the rest of the indexes (AOTI and OMMC) can be observed in the Table 4. AOTI is influenced by blend ratio.

This is probably due to the difference in accumulative moisture content between the two surfaces of the fabric in the given testing time, where at times, the moisture content on the top fabric surface is more than that on the bottom surface, and at times, the opposite is true. From the values of AOTI, it is observed that the values of cotton fabrics are higher than those of the bamboo cotton blended yarn fabrics.

The overall moisture management capability (OMMC) is dependent upon the absorption rate, one-way liquid transport index and liquid spreading speed. From the results, it can be stated that bamboo fabrics have low OMMC value. This may be due to minimum thickness of the 100% bamboo fabric as compared to the bamboo blended yarn fabrics.

4 Conclusion

It is observed that as the bamboo content increases in fabrics the wetting time decreases. The fabrics with 100% bamboo content give the highest absorption rate. In the maximum wetted radius test, it is seen that the higher the cotton content, the higher is the wetting radius. The higher bamboo content influences faster water spreading speed. In the AOTI test, it is found that the cotton fabrics show higher AOTI values compared to other fabrics. According to the results, it can be stated that, as the bamboo content increases, overall moisture management capability of the fabrics decreases. It is concluded that the increase in bamboo content results in decrease in the fabric areal density. This indicates that with the increase in blend ratio, it takes less time to wet a bamboo blend knitted fabric. These results indicate that the bamboo fabrics have good moisture management property and quick water transfer ability compared to other fabrics.

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