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Research Article

A COMPARATIVE STUDY OF DENIM FABRICS DEVELOPED USING RING AND ROTOR BAMBOO/COTTON YARNS

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ABSTRACT

In this paper, the functional properties of bamboo, cotton and bamboo/cotton blended denim fabrics have been studied. In this study, twenty denim fabric samples have been developed using ring and rotor spun yarns with different blend proportions of bamboo/cotton like 70:30, 50:50 & 30:70. The fabric samples were evaluated for their comfort and mechanical properties like air permeability, water vapour permeability rate (WVTR), Over all Moisture Management Capability (OMMC), crease recovery, tensile and tear strength. It is observed that with increase in the bamboo content in the blend improves the comfort and mechanical properties in both the ring and rotor yarn fabrics. Ring yarn fabrics exhibited better moisture management properties, water vapour transmission rate , tensile and tear strength than the rotor yarn fabrics. In contrary, rotor yarns have better air permeability, crease recovery, fabric assistance than the ring yarn fabrics. 70:30 bamboo/cotton blends have better comfort and mechanical properties than other blends

Keywords: Twill, Moisture, MVTR, Denim, OMMC, Crease recovery

INTRODUCTION

Denim fabrics are characterised by their high durability, longer washing cycles and ability to adapt to changing cultural and fashion trends in the market. It is considered a popular garment in the international market.[1] Nevertheless, the increased awareness among the customers on aesthetic and functional performance of the denim is the need of the present day market conditions.[2] Further, the physiological comfort determined by important fabric properties like air permeability, moisture management properties, UV protection are influenced by various constructional parameters of the fabric, type of fibre used. These factors have a significant influence on the porosity of the woven fabric structure. Total porosity of a woven fabric is dependent upon two types, viz. micro porosity and macro porosity.[3] Micro porosity is caused by void spaces among the fibres in the yarns and macro porosity is due to the void spaces amongst the yarns. In the bamboo fibre, there is more number of micro spaces in the fibre structure, which makes the fibre meet the functional requirements of the consumers[4].

Textile fabrics made of natural fibres and blends are more prone to microbial attack. The microbial growth will inflict a wide range of undesirable effects not only on the fabrics but also to the wearer. In the present changing environment, with increased awareness among the consumers about the health and hygiene, more emphasis is given to the fibres and fabrics which possess functional properties.[5] Denim is a popular garment liked by all the age groups and worn for an extended period of time. Bamboo is a relatively new regenerated fibre. It possesses inherent properties suitable for the manufacture of apparel and medical textiles. Regenerated bamboo fibre is obtained from the bamboo plant which is classified as grass. It grows quickly within three to five years to reach the harvest conditions.[6] Bamboo fibre has distinctive characteristics like high moisture absorption capacity, softness, brightness, ultra violet (UV) protection and more importantly anti-microbial properties. This property is widely accepted in medical textiles and tried in the wound care dressings. Bamboo fibres have high moisture absorbing capacity of around 13% which ensures comfort for various end uses in textiles like sportswear and other dress materials. In such situations, growth of microbes is unavoidable. Due to the inherent anti-microbial characteristic of bamboo fibres, it is blended with other natural and manmade fibres for the manufacture of knitted and woven materials. Bamboo fabrics are characterised by their good moisture absorbing capacity, sweat absorption and release and excellent air and water vapour permeability. They are also soft and easy to dye[7]. Hence, the positive attributes of the bamboo fibres have been utilised and in this research work, yarns and denim fabrics were made using bamboo- cotton blends and their comfort properties were studied and analysed keeping in mind, the growing demand among the consumers of denim fabrics with functional and aesthetic properties.

MATERIALS AND METHODS

Twenty denim fabric samples were developed with 3/1 twill construction in a loom using bamboo, cotton and bamboo/cotton blended yarns in the blend proportions of 70:30, 50:50 & 30: 70. The fabric specifications was maintained 56 EPI and 44 PPI for ring and rotor yarn fabrics with GSM of 285 to 300. Indigo dyed warp yarns (2% shade) and undyed grey weft were used as weft for the denim fabric construction. Desizing was carried out using amylase enzyme, hot and cold washed, scoured and bleached with sodium hydrosulphide. The fabric samples were then finished with amylase enzyme. The fabrics were tested for their comfort properties like air permeability, Moisture vapour transmission rate (MVTR) using cup method, crease recovery, overall moisture management properties (0MMC) and mechanical properties like tensile and tear strength using standard test procedures.

TEST METHODS

The property and the test methods are shown in Table 1

Table 1 Property and Test method

S. No.	Property	Test method
1	Air permeability	ASTM D 737-04(2016)
2	Water vapour transmission rate (MVTR)	ASTM E 96
3	Crease recovery	ASTM D - 1295
4	Over all moisture management capability (OMMC)	AATCC 195 - 2009
5	Tear strength	ASTM D 1424 – 09 -2013

RESULTS AND DISCUSSION

Air permeability

The air permeability of the fabrics made out of ring and rotor yarns is shown in Table 2

Table 2 Air permeability of fabrics

Count / Blend	Ne 10		Ne 16	
	Ring	Rotor	Ring	Rotor
100% Bamboo	136	165	140.8	168
70:30 B/C	112	134	119	137
50:50 B/C	93.6	116	99.2	119.2
30:70 B/C	84.2	101	76	95
100% Cotton	73.3	95	72	84

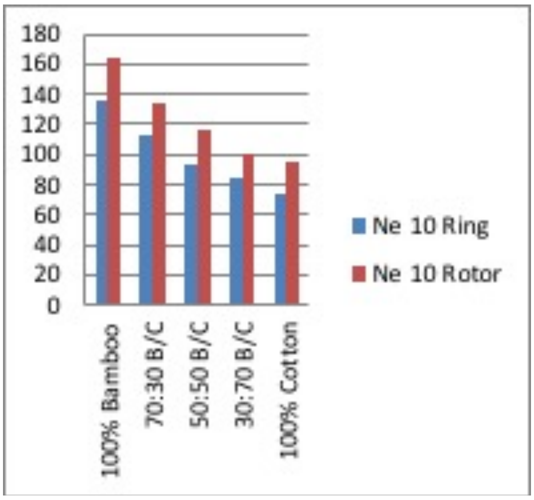

Figure 1 Air permeability of Ne 10 Ring & Rotor fabrics

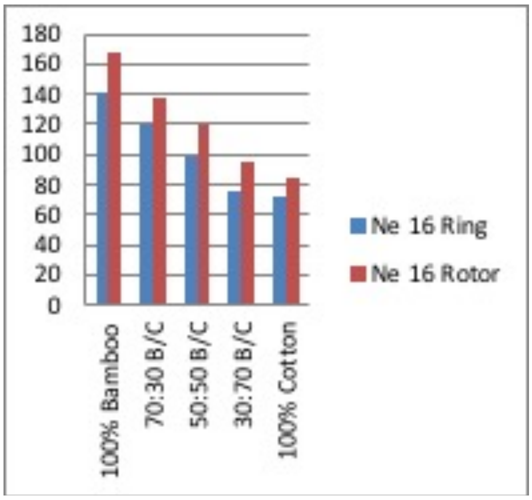

Figure 2 Air permeability of Ne 16 Ring & Rotor fabrics

From Table 2 & Figures 1 and 2, it is observed that the air permeability of rotor yarn fabrics have higher air permeability than the corresponding ring yarn fabrics by 12% to 20%. in both the yarn counts. The higher air permeability of the rotor yarn fabrics is attributed to the presence of wrapper fibres on its surface and also due to the floats in the twill fabric construction. Rotor yarns are characterised by its higher bulkiness and dense nature. Due to this property, it allows more air to pass through the fabric and also flexibility is provided by the yarn due to higher crimp. 100% bamboo fabrics show higher air permeability by 18% to 30% than 100% cotton and its blends. It is attributed to the presence of more micro spaces in the bamboo fiber, which allow higher air flow rate in to the fabrics. The air permeability of a fabric is affected by the yarn diameter, yarn structure, fabric construction, crimp, cover factor of the fabric and pores between the fibres and the yarns. Air permeability of the fabrics significantly influences the thermal comfort of the human body for maintaining proper body temperature. In the blends of ring and rotor yarn fabrics, air permeability decreases with increase in cotton component due to the increase in fabric thickness and also less porous structure of cotton. A twill fabric is more permeable to air than the plain woven fabric due to the floats in the warp direction.

Tensile strength of Fabrics

Tensile strength of the fabrics tested in Instron. Tensile strength of the Fabrics tested is shown in Table 3

Table 3 Tensile strength of the Fabrics

Count / Blend	Ne 10 Ring (Warp + Weft)	Ne 10 Rotor (Warp + Weft)	Ne 16 Ring (Warp + Weft)	Ne 16 Rotor (Warp + Weft)
100% Bamboo	35.39	33.12	37.15	35.66
70:30 B/C	29.56	27.76	32.37	30.42
50:50 B/C	27.32	24.58	30.26	27.83
30:70 B/C	23.46	20.64	25.70	22.61
100% Cotton	21.85	18.57	23.17	20.15

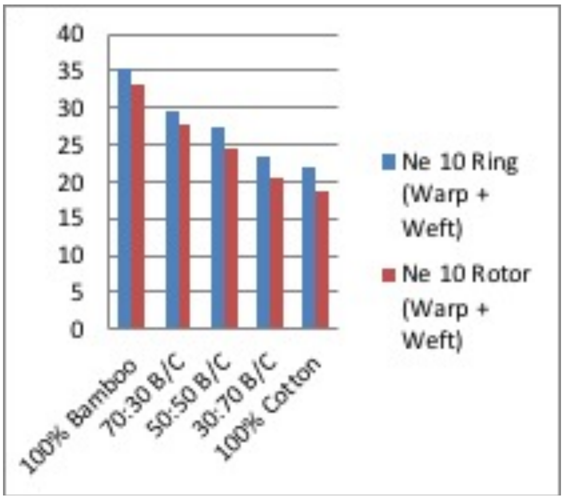

Figure 3 Tensile strength of Ne 10 Ring and Rotor

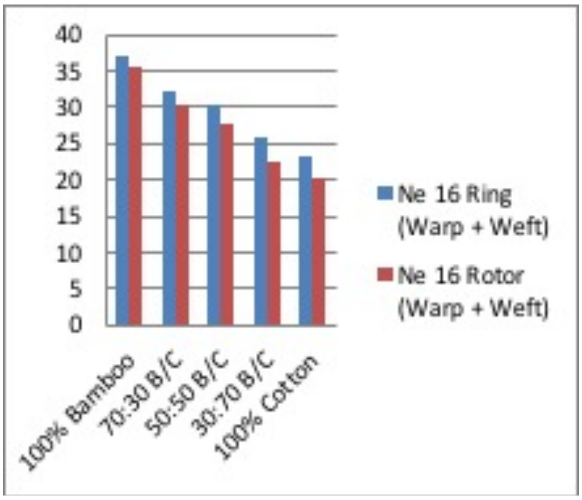

Figure 4 Tensile strength of Ne 16 Ring and Rotor

Table 3 and Figures 3 & 4 show the tensile strength of the ring and rotor yarn fabrics. It is observed that the tensile strength of the rotor yarn fabrics is distinctly inferior by 5% to 15% to the ring yarn fabrics. This is mainly attributed to the lower single yarn breaking strength of the rotor yarns. With decrease in the bamboo component in the blend, the tensile strength of the fabrics is correspondingly reduced.

Fabric Assistance

Fabric assistance is the relationship between the ratio of strip strength per yarn and single yarn strength (S/Y) used to quantify the fabric assistance property of woven fabrics. It is dependent upon the frictional forces acting between warp and weft yarns on the fabric structure, which influence the fabric strength. Fabric assistance arises due to the interlacement of warp and weft yarns and, during tensile strength testing, the fabrics act like one body than as individual threads in the free state . Fabric assistance of Ring and Rotor yarn fabrics is shown in the Table 4

Table 4 Ratio of fabric strip strength per yarn and single yarn strength

Count / Blend	Ne 10 Ring Warp + Weft	Ne 10 Rotor Warp + Weft	Ne 16 Ring Warp + Weft	Ne 16 Rotor Warp + Weft
100% Bamboo	1.25	1.31	1.27	1.35
70:30 B/C	1.19	1.26	1.19	1.28
50:50 B/C	1.13	1.22	1.11	1.16
30:70 B/C	1.09	1.15	1.07	1.12
100% Cotton	1.04	1.06	1.03	1.05

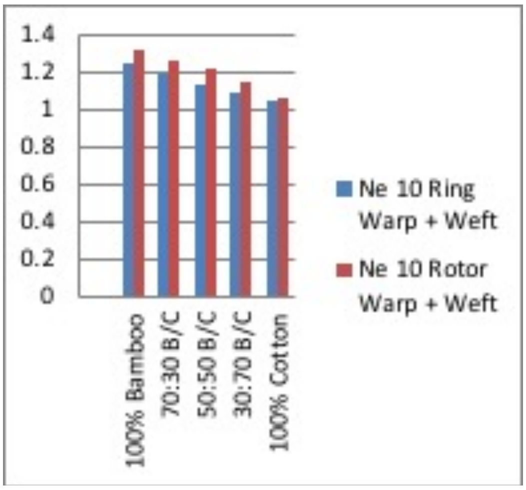

Figure 5 Fabric Assistance of Ne 10 Ring & Rotor

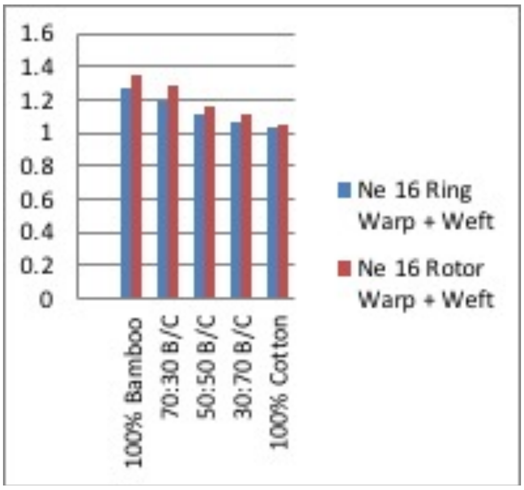

Figure 6 Fabric Assistance Ne 16 Ring & Rotor

From the results, the strength fall in rotor spinning comes down from yarn to fabric stage. However, the strength ratio improves from yarn to fabric stage. This is mainly ascribed to the better fabric assistance of the rotor yarn fabrics in relation to ring spun yarns. Fabric assistance of the rotor yarns is higher by 4% to 6% than the ring yarn fabrics in both warp and weft directions. It might be due to the non-load bearing wrapper fibres which get trapped in the fabric structure and contribute for the higher fabric assistance. This trend is observed in all the blends in both counts.

Tear Strength

The behaviour of the woven fabrics under impact load is different from that under tensile load. In tensile load, all the yarns in the direction of tension share the load, whereas in the case of tearing, only few yarns share the load. Tear strength of the fabrics in both directions is shown in Table 5

Table 5 Tear strength of the fabrics

Property / Blend	Tear Strength Ne 10				Tear Strength Ne 16			
	Ring		Rotor		Ring		Rotor	
	Warp way	Weft way	Warp way	Weft way	Warp way	Weft way	Warp way	Weft way
100% Bamboo	5132	4315	3456	2729	5337	4633	4077	3125
70:30 B/C	4723	3915	3161	2412	5056	4212	3522	2628
50:50 B/C	4070	3281	3008	2295	4518	3588	2920	2094
30:70 B/C	3455	2645	2472	1821	3315	2518	2215	1521
100% Cotton	2812	2243	2215	1639	3105	2218	1725	1210

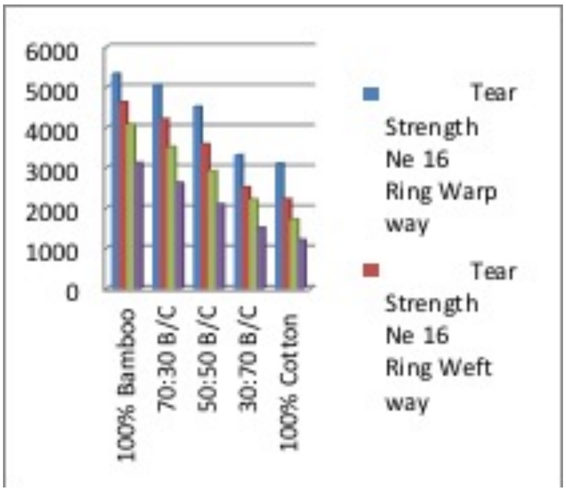

Figure 7 Tear strength of Ne 10 Ring & Rotor fabrics

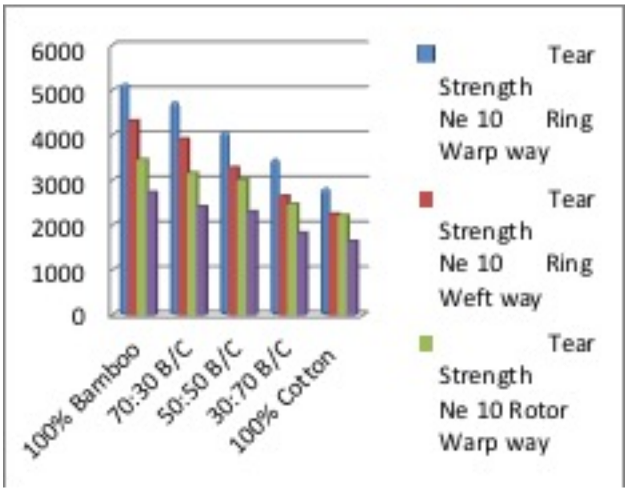

Figure 8 Tear strength of Ne 16 Ring & Rotor fabrics

Table 5 and Figures 7 & 8 show that the warp-way tear strength is always higher than the weft-way tear strength due to the lower number of picks/unit length maintained in the fabric construction. The difference being 15 % to 28 % in ring-spun fabrics and 21% to 30% in rotor spun fabrics The tear strength of 100% bamboo yarn fabrics in both the ring and rotor yarns shows higher tearing due to the inherent strength of the bamboo fibres. However, in the subsequent blends with the cotton fibres, the tear strength gradually gets decreased. It is attributed to the lower strength of the cotton fibres which cannot withstand the impact load. Among the various blend proportions, 70:30 bamboo-cotton blend shows better tear strength than its counterparts. The tear strength of the fabrics made out of rotor- spun yarns is 20 – 27% lower than that of the fabrics made from ring-spun yarns due to the lower yarn tenacity of the rotor yarns. The weft-way tear strength is found to be distinctly lower than the warp-way tear strength. It is attributed to the difference in the number of ends and picks per inch maintained in the fabric.

Crease recovery

The crease recovery of the fabrics was carried out on the vertical strip method according to ASTM standard. Crease recovery of the fabrics is shown in Table 6

Table 6 Crease recovery of fabrics

Count / Blend	Ne 10	Ne 10	Ne 16	Ne 16
	Ring	Rotor	Ring	Rotor
	Warp+ Weft	Warp+ Weft	Warp+ Weft	Warp+ Weft
100% Bamboo	153	165	162	173
70:30 B/C	135	154	154	168
50:50 B/C	120	146	142	157
30:70 B/C	110	125	122	139
100% Cotton	102	117	109	125

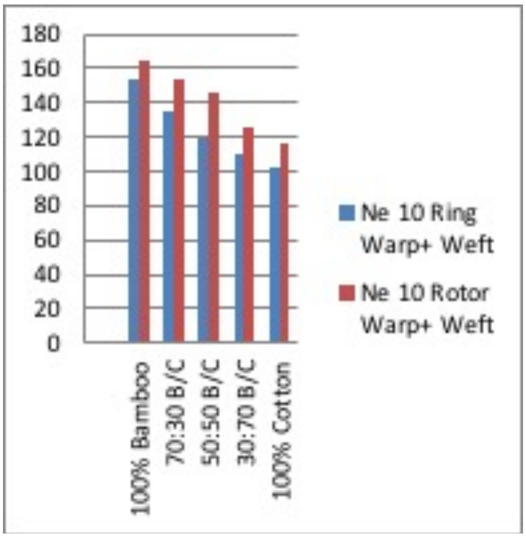

Figure 9 Crease recovery of Ne 10 Ring & Rotor fabrics

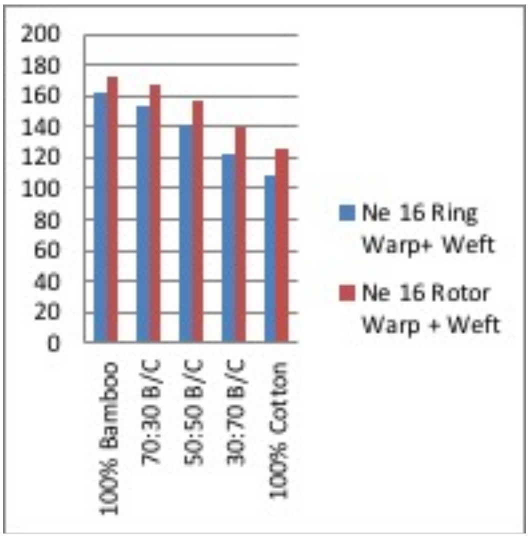

Figure 10 Crease recovery of Ne 16 Ring & Rotor fabrics

From Table 6 and Figures 9 & 10, it is observed that the crease recovery of rotor spun yarn fabrics is higher than that of the ring yarn fabrics by 7% to 15% . The higher crease recovery of rotor yarn fabrics is attributed to the higher diameter and higher bulkiness which make the fabric more resilient. Crease recovery of 100% bamboo fabrics is higher than 100% cotton and its blends. It is attributed to the smooth surface structure and lower resistance to bending and recovery of the bamboo fibers. With increase in cotton component in the blend, crease recovery decreases which is as expected due to the higher resistance offered by the cotton fibres.

Water Vapour Transmission Rate (WVTR)

The water vapour transmission of the fabric samples has been measured using the cup method according to the ASTM E 96 standard. This method is based on the evaporation time 24 h. of water contained in a cup and the water vapour permeability is determined by the weight loss. The water vapour permeability of the fabrics is shown in Table 7.

Table 7 Water vapour permeability of ring and rotor fabrics

Count / Blend	Ne 10		Ne 16	
	Ring	Rotor	Ring	Rotor
100% Bamboo	1558	1713	1878	2059
70:30 B/C	1496	1662	1799	1944
50:50 B/C	1389	1579	1642	1845
30:70 B/C	1368	1492	1502	1752
100% Cotton	1180	1399	1492	1716

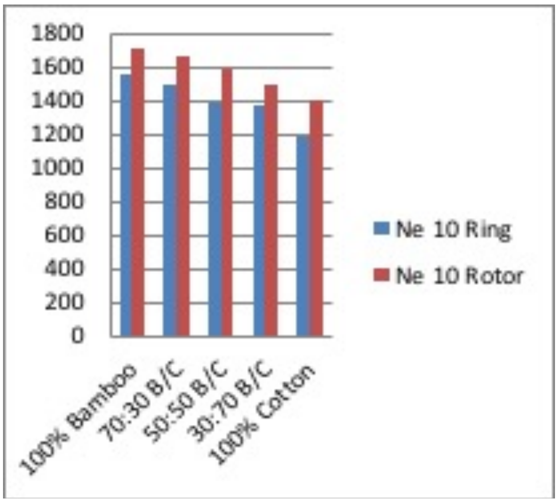

Figure 11 WVTR of Ne 10 Ring & Rotor fabrics

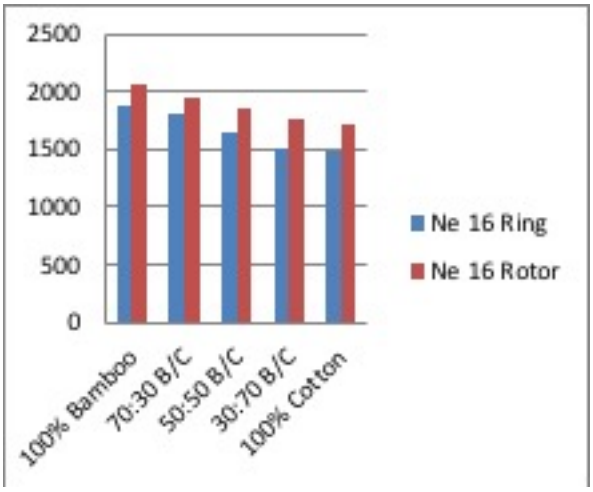

Figure 12 WVTR of Ne 16 Ring & Rotor fabrics

Water Vapour Transmission Rate (WVTR) of bamboo, bamboo/cotton blended fabrics of ring and rotor yarns is shown in Table 7 and Figures 11 & 12. It is observed that fabrics made out of rotor yarns have higher water vapour transmission rate than the ring yarn fabrics by 8% to 14%. It is also seen from the fabrics that the WVP of fabrics with Ne 16 is higher than Ne 10 fabrics. It is attributed to the lower yarn diameter fabric thickness than Ne 10 fabrics. Bamboo fabrics have higher WVP than the cotton fabrics due to the presence of micro spaces and less pore size which allow the water vapour to permeate more easily into the fabric structure. However, in the blends, WVP is reduced due to the presence of cotton fibres and higher yarn diameter and fabric thickness. The WVP of rotor fabrics is less due to its higher bulkiness and yarn diameter and hence the flow rate is directly proportional to the fabric thickness due to the higher fabric cover of the rotor fabrics.

Overall Moisture Management Capability (OMMC)

Moisture management tester (MMT) (SDL Atlas, is used for testing the liquid moisture transfer properties of the fabrics. This instrument is capable of determining the liquid transfer in multiple directions through fabrics like spreading of liquid outward to inner surface of the fabric, wetting time of top and bottom surface, absorption rate etc., and gives the result as OMMC index of the fabrics. The higher the OMMC the better the moisture transfer of the fabrics. Moisture management properties of the fabrics is shown in Table 8.

Table 8 Overall Moisture Management Capabilities (OMMC)

Blend / Property	Ne 10		Ne 16	
	Ring	Rotor	Ring	Rotor
	OMMC	OMMC	OMMC	OMMC
100% Bamboo	1022.81	1097.20	893.92	978.25
70:30 B /C	843.72	879.82	744.62	862.15
50:50 B / C	728.69	788.45	654.25	731.21
30:70 B / C	653.20	716.42	622.42	701.21
100% Cotton	546.45	616.25	562.25	620.62

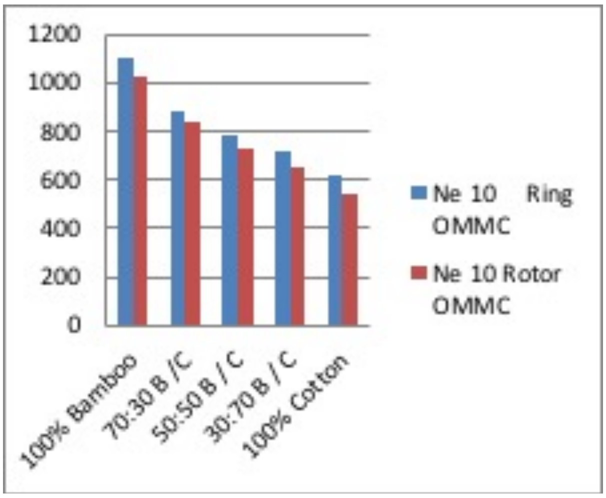

Figure 13 OMMC of Ne 10 Ring & Rotor fabrics

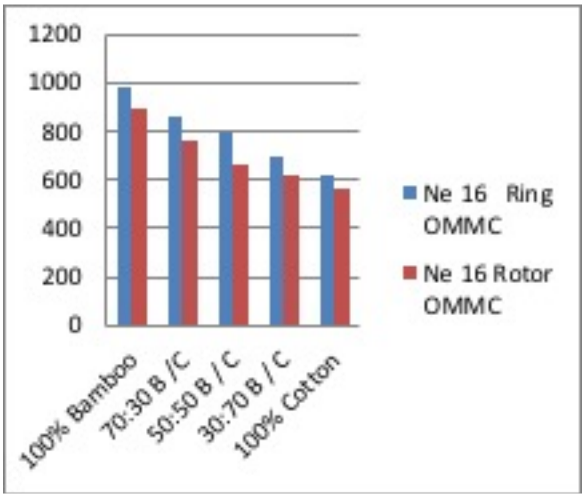

Figure 14 OMMC of Ne 16 Ring & Rotor fabrics

From Table 8 and Figures 13 & 14, it is observed that the liquid transfer properties (OMMC) of rotor yarn fabrics Ne 16 is better than the ring yarn fabrics by 6% to 11% . It is due to the yarn diameter of the ring yarn, close packing of fibers in the yarn and also close spacing in the fabrics which takes longer time for the liquid to traverse through them. Hence wetting time (Top/ Bottom), Spreading time (Top/Bottom), Absorption rate (Top/ Bottom) are more for coarser yarns than the finer yarns. Hence, yarns of lower linear density and lower fabric thickness would result in fast liquid spreading behaviour than its coarser yarn counterparts. OMMC of bamboo fabrics is higher than the cotton fabrics due to the porous structure of the bamboo fibres and higher moisture absorbing capacity. However, OMMC of blended fabrics decreases with the decrease in bamboo fibre content due the presence of cotton fibres. On the other hand, lower OMMC of rotor yarn fabrics is attributed to its inherent yarn structure, fabric thickness and bulkiness, which takes time for wetting and spreading through the fabrics.

CONCLUSION

In this study, twenty denim fabric samples developed from bamboo/cotton blends using ring and rotor yarns are critically analysed for their comfort and mechanical properties**.** The tensile and tear strength of the ring yarn denim fabrics made out of bamboo fabrics and 70:30 bamboo/cotton blends are better by 5% to 15% and 15% to 25% than the rotor yarn denim fabrics. However, rotor yarn denim fabrics have more fabric assistance than the ring yarn fabrics. The air permeability of the bamboo and 70:30 bamboo/cotton blended rotor yarn denim fabrics are better by 12% to 20% due to more micro spaces present in the bamboo fibres. Rotor yarn denim fabrics have more air permeability than the ring yarn fabrics due to the higher bulk, higher diameter and open structure of rotor yarns. Crease recovery of rotor yarn denim fabrics is better by 7% to 15% than the ring yarn denim fabrics. It is due to the resilient nature and more fabric thickness of the rotor denim fabrics. Bamboo and bamboo / cotton blend of 70:30 made out of ring yarn denim fabrics have better water vapour transmission rate than the other blends, which is due to the high hygroscopic nature of the bamboo fibres. The water vapour transmission rate of the rotor yarn denim is inferior due to the fabric thickness. Moisture management properties of bamboo and 70:30 bamboo cotton blends of ring yarn denim fabrics have higher OMMC by 6 % to 11% than the rotor yarn denim fabrics. It is due to the fabric thickness and higher bulkiness, which takes more time for the moisture to spread, absorb and traverse through.

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