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Moisture transport behaviour of Eli-Twist knitted fabric and its comparison with fabric made from yarns spun on different spinning systems

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In this study, moisture management properties of knitted fabrics from Eli-Twist polyester and cotton yarns have been investigated. A comparative analysis with knitted fabrics from conventional ring-spun, siro-spun and compact yarns has also been made to assess its suitability. It is observed that polyester and cotton fabrics made from Eli-Twist yarn show very good permeability and moisture management characteristics.

Keywords: Cotton, Drying rate, Eli-Twist yarn, Moisture management properties, Polyester, Siro yarn, Water vapour permeability

1 Introduction

Clothing not only protects the wearer from external atmospheric condition but also maintains a balance between the outer environment and the body. Metabolic heat is generated in the body continuously that leads to moisture generation. In order to provide comfort to the wearer, the generated moisture should be transmitted away from the body, thereby maintaining the thermal balance in the body. The clothing plays an important role in maintaining the thermal balance. Pores and micro pores present in the clothing can influence the transfer of moisture from the body. Yarns being the basic structural unit of fabric, both inter & intra yarn pore in the clothing is responsible for the transmission characteristics of moisture and heat. Any change, either in yarn and fabric structure, can cause significant change in the geometry of the macro and micro pores in the fabric[1]. Transmission of generated moisture and permeable characteristics are, thus, going to be influenced with change in the pore characteristics. A fabric with good moisture management characteristics is preferred for comfort. In recent times, a growing interest for moisture management fabric has been reported even in flame retardant apparel fabric besides sports and active wear[2]. Change in the structure of a yarn can be brought about by changing the raw material, process parameters, spinning system or any combination of the these three. A change in spinning system modifies the arrangement of fibres and the structure of yarn leading to thechange in its physical and mechanical properties[3].

Over the years, continuous attention has been paid for improvement of yarn quality. In an attempt to improve productivity and quality, several spinning systems were launched in the market[4-6]. Few modifications in the existing ring spinning system were attempted to improve the unevenness and reduce hairiness. Siro spinning was able to provide improvement in the evenness, while Eli-Twist and compact spinning systems were able to produce yarn with improved uniformity and significantly reduced hairiness[4,7,8]. Knitted fabric generally provides more bulk and openness. Such fabrics are reported to show better moisture transmission and permeable characteristics. Higher extensibility of knitted fabric causes less impediments in the movement and are preferred for active sportswear in comparison to woven fabrics.

The behaviour of a textile material in presence of moisture is important. Although knitted cotton fabrics are comfortable, but the fabrics made from blends with other fibres are always preferred for functional and aesthetic requirements that cannot be met by cotton only. However, change in both functional and aesthetic behaviour can also be brought about by preparing the yarn through different spinning systems. Hence, present work has been aimed to study the

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impact on the moisture transportation properties of knitted fabrics made from polyester and cotton fibres spun on different spinning systems. The moisture transportation and drying behaviour decide a diverse range of textile applications, including casual wear, sportswear, and protective wear from their comfort, processing and cleaning point of view[9,10]. Air permeability is an important measure of fabric comfort, as it decides the air moving through it, leaving a dry feeling on the wearer skin.

Eli-Twist spinning system is novel development, which has drawn significant attention in industry in recent time. It posses combine attributes of both Siro and compact spinning systems, through fibre doubling during spinning while compaction of the structure is assisted by air suction. No published research finding has been found on the moisture management behavior of Eli-Twist knitted fabric to the best of our knowledge. In the present work, investigation on moisture management properties of knitted fabrics from Eli-Twist polyester and cotton yarn have been reported. A comparative analysis with knitted fabric from conventional ring-spun, Siro spun, compact yarn hasalso been made.

2 Materials and Methods

2.1 Materials

The Eli-Twist yarn was produced on Elite compact set ring frame (LR60/AX) from Suessen,maintaing a distance of 8 mm between two rovings in the drafting at a negative pressure of 28-30 mbar. Single ring and compact yarns were spun on a Lakshmi spinning line while Siro yarn was produced on spinning (LR60) machine from Lakshmi machine works. The detail of sample preparation plan is given below:

Parameters		**Value**
Fibre	:	Cotton (H-4)
		Polyester
Fibre length	:	Cotton-30 mm (UHML)
		Polyester- 38mm
Fibre fineness	:	Cotton-1.5 denier (4.2 Micronaire)
		Polyester- 1.2 denier
Spinning system	:	Eli-Twist, Siro, Ring, Compact
Count produced	:	29.5 tex(20 Ne)
Twist factor	:	40 (turns/cm × $tex^{1/2}$)

Single jersey knitted fabrics were made on Delha socks knitting machine of diameter 8.9cm using 22 machine gauge. The structural parameters of prepared knitted fabrics are given in Table 1.

2.2 Fabric Pre-treatment

The grey knitted fabrics were given pre-treatment to remove impurities. Scouring treatment with 1% NAOH and 2% anionic surfactant in 1 litre of water was given. The treatment was carried out for 45 min at 100^{o}C. The samples were then washed for 15 minfollowed by bleaching with NaOCl (1-2gpL) for 1 h at room temperature. Anti-chlorine treatment (2g $Na_2S_2O_4$ in 1 litre of water for 15 min at 45^{o}C) was given for neutralization. After treatment, the samples were thoroughly rinsed with water at neutral *p*H and then kept in a room for dryingand conditioning at 27^{o}C.

2.3 Test Methods

2.3.1 Air Permeability and Water Vapour Permeability

The fabrics were tested for air permeability with a test head area of 5cm^2 and standard pressure of 98 Pa.

The water vapour permeability test was carried out on water vapour permeability tester. Each fabric test specimen was pre-conditioned for 4 h under standard tropical atmosphere. The testing was done in accordance with BS 7209, BS 3424 standard. The water vapour permeability (WVP) in g/m²/day was calculated using the following relationship:

$$\text{WVP} = \frac{24M}{A.T}$$

where M(g) is the loss in mass of assembly over the time period *T*; *T*, the time between successive weighing of assembly in hours; and *A*, the 0.0054113 m² is the exposed area of test specimen.

Table 1 — Structural parameters of polyester and cotton knitted fabrics

Spinning system	Yarn composition	Courses /inch	Wales /inch	Loops / unit area	Loop length, mm
Eli-Twist	Cotton	30	24	720	4.12
Compact	Cotton	38	26	988	3.98
Siro	Cotton	42	30	1260	3.92
Ring	Cotton	44	30	1320	3.96
Eli-Twist	Polyester	28	26	728	3.75
Compact	Polyester	36	26	936	3.8
Siro	Polyester	40	28	1120	3.78
Ring	Polyester	43	28	1204	3.82

2.3.2 Drying Rate

Drying rate of the fabric was measured on a dry rate tester. One mililiterof distilled water was spread uniformly over a fabric of the size 15 cm × 15 cm to wet. The mass of the fabric was measured before the start of the test and after 15 min of drying. The drying rate is expressed as a percentage loss of water content from fabric.

2.3.3 Moisture Management Properties

All fabrics were tested for moisture management properties following AATCC Test Method 195-2009. The test solution (simulating perspiration) spreads in three directions after arriving on the top surface of the fabric specimen, i.e. spreading outward on top surface, transferring from top surface to the bottom surface and spreading outward on bottom surface. As represented in Fig. 1, the resistance of each couple of proximate metal rings changes in pressure of this solution, which can conduct electricity. The moisture management is characterized by the wetting time, absorption rate, maximum wetted radius, spreading speed and one way transport capacity (OWTC) parameters.

3 Results and Discussion

Moisture management properties of single jersey cotton and polyester knitted fabrics prepared from different yarns have been investigated. Air permeability, drying rate and water vapour permeability for the same fabric are also measured. Analysis of variance has been made on experimental results using statistical software (Table 2).

3.1 Air Permeability

The effect of yarn type on air permeability is represented in Fig. 2 (a). It is observed from Fig. 2 (a) that both cotton and polyester single jersey knitted fabrics made from Eli-Twist spun yarn have higher air permeability than the rest.

Permeability of a fabric depends on the degree of openness in it. Both inter and intra yarn voids are important. The fuzziness of the yarn surface also

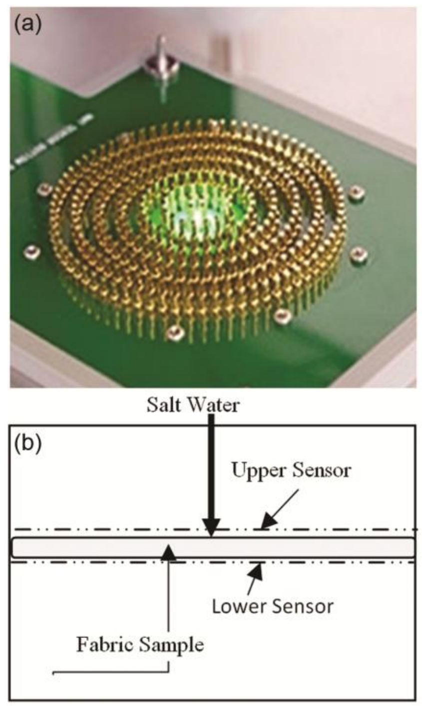

Fig. 1 — (a) Moisture management tester and (b) sketch of sensor

Table 2 — ANOVA results for properties of different knitted fabric

Property	Effect of spinning system		Effect of yarn composition	
	F ratio	p value	F ratio	p value
Air permeability, $cm^3/cm^2/s$	61.96	0.0033	2718	0.0001
Water vapour permeability, $g/m^2/day$	10.37	0.043	209.29	0.0007
Dry rate, %/min	4.09	0.1384	278.48	0.0004
Wetting time, s				
Top	5.35	0.10	14.07	0.0331
Bottom	4.99	0.11	5.29	0.1049
Absorption rate, %/s				
Top	2.60	0.23	0.43	0.5585
Bottom	4.99	0.11	5.30	0.1049
Max wetted radius, mm				
Top	1.00	0.50	25.00	0.0154
Bottom	1.00	0.50	27.00	0.0138
Spreading speed, mm/s				
Top	0.79	0.58	25.70	0.0148
Bottom	0.70	0.61	12.62	0.0380
One way transport index	1.74	0.33	102.497	0.0021
Overall moisture management	17.68	0.02	1079.35	0.0001

p value for 95% significance ≤ 0.05.

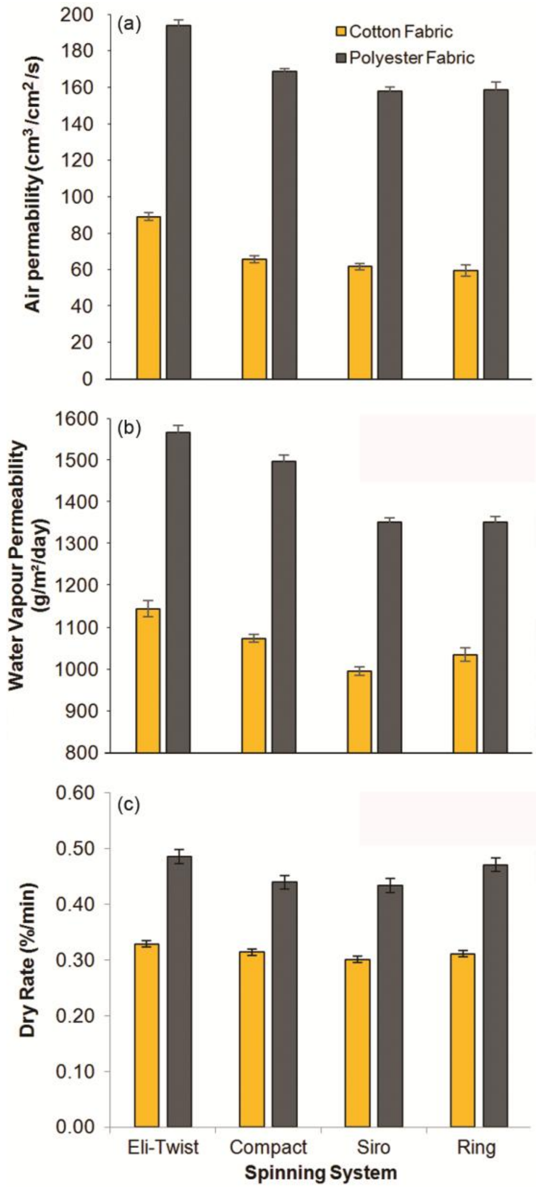

Fig. 2 — Effect of yarn type in knitted fabric on (a) air permeability, (b) water vapour permeability and (c) dry rate

offers resistance to air flow. The packing density of Eli-Twist yarns has been reported to be higher[3]. The surface of Eli-Twist yarns is smooth and less hairy. The diameter of Eli-Twist yarns is also lower as compared to other yarns used here. The fabric density (WPI and CPI) at relaxed state was found to be less for Eli-Twist knitted fabric (Table 1), resulting in more inter yarn space for fabric made from Eli-Twist yarn.The air permeability is, therefore, more for fabrics made from Eli-Twist yarns.

The air permeability is lower for cotton knitted fabrics as compared to polyester knitted fabrics. Hairiness and larger diameter of cotton yarns are responsible to cause hindrance to air flow. It is observed from Table 2 that the effects of spinning system and yarn composition on air permeability are significant.

3.2 Water Vapour Permeability

The water vapour permeability results are shown in Fig. 2(b). Following observations are made:

- Cotton knitted fabrics made from Eli-twist and compact yarns show higher water vapour permeability, while it is similar for rest of the fabrics.
- Polyester knitted fabrics made from Eli-Twist and compact yarns show higher rate of water vapour permeability than those from ring and Siro spun yarn fabrics.
- Polyester knitted fabrics are superior in water vapour permeability as compared to cotton knitted fabric.

ANOVA results suggest that the yarn spinning systems and yarn composition have significant effects on water vapour permeability, at 95% confidence level.

Fabrics from Eli-Twist and compact yarn create more open loops per unit area, which help in giving easy escape route for moisture. However, the same made from hairy ring and Siro spun yarn makes the inter yarn spaces narrower and fuzzy. Thus, it offers more resistance to vapour flow. Polyester fibre does not absorb any moisture as compared to cotton. The fibre and the yarn out of it, being of higher circularity, show less tortuous moisture escaping routes between yarns and fibres. Hence, vapour transmission is easier in polyester fabrics.

3.3 Dry Rate

Figure 2(c) is show the drying rate behaviour of knitted fabrics. It is observed from the figure that the drying rate of polyester knitted fabric is significantly high as compared to cotton knitted fabric.

Spreading of liquid depends on capillary transportation and moisture absorbing capacity of the constituent fibres. Capillary transportation can take place through inter-yarn and intra-yarn space. Geometry of such space depends not only on the inter-yarn spaces but also on the orientation and packing of fibres within yarn. Polyester wicks faster than cotton and does not hold water within the fibre. Thus, drying rate will always be faster in polyester fabrics.

The difference in drying rate of fabrics made from different yarns is not much for cotton yarns. The impact of different yarn spinning systems (Eli-twist, compact, ring and siro) on drying rate is found to be insignificant. In this case, the drying is dominated by absorption of moisture by fibre.

3.4 MoistureManagement Properties

The moisture management properties of cotton and polyester knitted fabrics are given in Table 3. The maximum wetted radii both at the top and bottom of the knitted fabrics are shown in Fig. 3.

The following observations are made from results presented in Table 3 and Fig. 3:

- The wetting time for bottom surface is little more than the top surface, irrespective of yarn composition and technology used for its production.
- Fabrics from Eli-Twist yarn show lowest top and bottom wetting time whereas siro knitted fabric takes highest time to wet on both top and bottom surfaces.

Table 3 — Moisture Management properties of cotton and polyester knitted fabrics of spinning systems

Spinning system	Yarn	Wetting time, s		Absorption rate %/s		Max wetted radius mm		Spreading speed mm/s		OWTC	OMMC
		Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom		
Eli-Twist	Cotton	3.40	3.47	29.65	43.67	20	20	4.43	4.49	152.19	0.548
Compact	Cotton	3.67	3.68	28.02	42.24	20	20	3.33	3.42	144.16	0.517
Siro	Cotton	3.69	3.72	25.75	41.68	20	20	3.41	3.35	123.81	0.487
Ring	Cotton	3.53	3.76	26.38	41.84	20	20	3.69	3.67	140.39	0.517
Eli-Twist	Polyester	3.27	3.29	30.32	56.77	30	30	5.22	4.89	285.91	0.738
Compact	Polyester	3.32	3.34	26.76	49.52	25	25	5.62	5.64	227.34	0.688
Siro	Polyester	3.58	3.74	29.05	51.97	25	25	4.90	4.55	252.80	0.686
Ring	Polyester	3.28	3.59	26.22	52.06	25	30	5.43	5.50	264.45	0.707

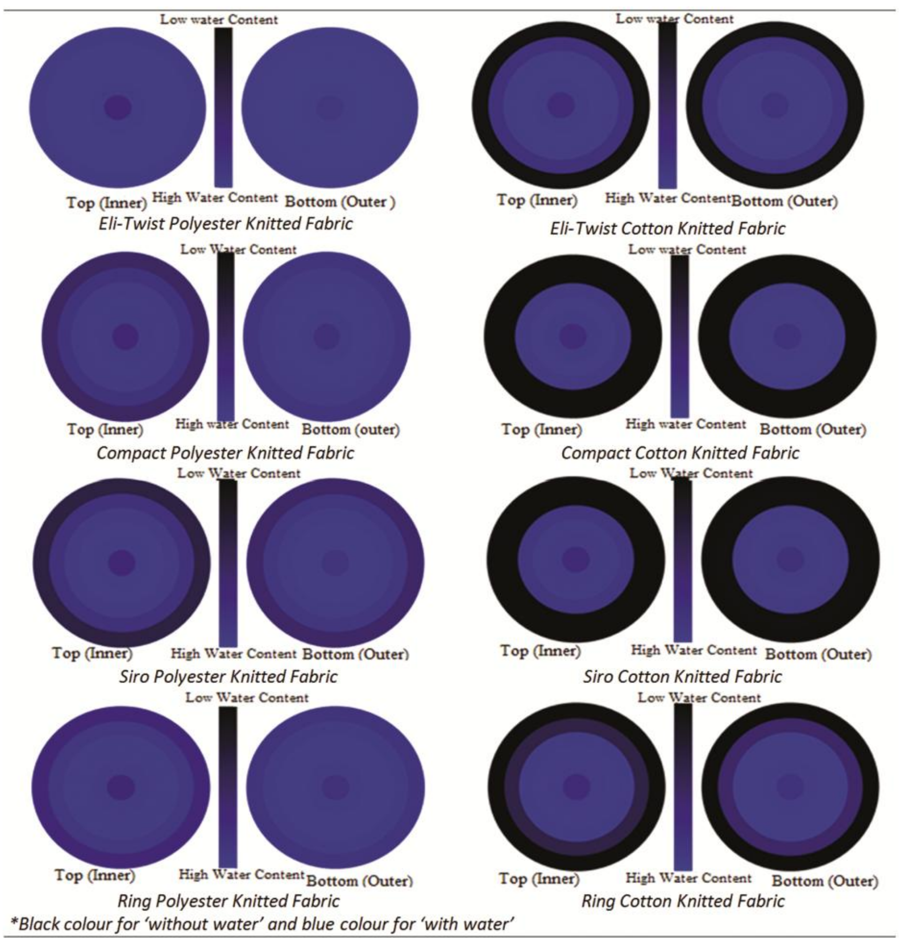

Fig. 3 — Water location of knitted fabrics

- The effect of yarn composition is found to be significant on top wetting time. However, the effect of spinning system on top and bottom wetting time is insignificant (Table 2).
- Absorption rate is always much greater for bottom surface of fabric than the top surface of fabrics under study. Absorption rate at bottom surface for polyester fabric is greater than that in cotton fabric.
- Wetted radius is same for both top and bottom surface. The wetted radius is observed to be more for polyester fabric than for cotton fabric.
- Fabrics from Eli-Twist yarn have higher wetted radius both at top and bottom irrespective of yarn composition.
- Spreading speed, practically, is the same for both top and bottom surfaces. However, spreading speed is more for polyester knitted fabric as compared to the cotton knitted fabric.

The ANOVA analysis shows that the effect of spinning system and yarn composition on spreading speed is significant (Table 2).

Since water is dropped on the top surface of the fabric it spreadsfaster on top surface. The migration of water from top to bottom surface is due to gravity and wicking. The process of migration of water continues for slightly longer period of time.

The higher absorption rate for bottom surface is due to gravity force that acts in the inter yarn space. Maximum wetted radius is observed in polyester knitted fabric. This is due to low surface energy of polyester in comparison to cotton. Longer intra fibre capillary channel (being devoid of short fibres) and inability of diffusion within the fibreare responsible.

Fabric made from Eli-Twist yarn shows minimum wetting time. Finer capillary within the yarn increases the capillary pressure, and thus the maximum absorption rate and faster spreading speed in fabric made from Eli-Twist yarn are observed.

3.4.1 One-way Transport Capacity (OWTC)

The effect of different spinning system on accumulative one-way transport capacity has been represented in Fig. 4(a).The polyester knitted fabrics, in general, show higher OWTC as compared to cotton knitted fabric. Higher wicking capability of polyester fibre is responsible for this. The smaller diameter of polyester yarn due to higher packing density will lead to more inter yarn open space in corresponding fabrics, thereby facilitating the transmission. Consistent trend is not observed in OWTC values in fabrics made from both cotton and polyester yarns made using other spinning technologies.

Fabrics made from polyester Eli-Twist yarn show, highest accumulative one-way transport capacity as compared to ring and siro yarns due to absence of hairs on yarn. When hairiness is less, the inter yarn spaces will be more efficient in transporting the liquid. Thus, OWTC for fabric from Eli-Twist yarn is higher.

3.4.2 Overall Moisture Management Capacity (OMMC)

The overall ability of the fabric to manage the transport of liquid moisture was expressed by an index known as overall moisture management capacity. The overall moisture management capacity (OMMC) is expressed by the followingequation:

$$\mathrm{OMMC} = 0.25 \times AR_{bottom} + 0.5 \times \mathrm{OWTC} + 0.25 \times SS_{bottom}$$

where AR is the absorption rate; OWTC, the one-way transport capacity; and SS, the spreading speed.

It may be observed from Fig. 4(b) that the polyester knitted fabrics show higher value of OMMC as compared to cotton knitted fabric. The moisture management grading for polyester knitted fabric is better than that of cotton knitted fabric

The fabrics from Eli-Twist yarn show better moisture management characteristics with highest overall moisture management capacity (OMMC). The Eli-Twist yarn due to its compact structure exhibits

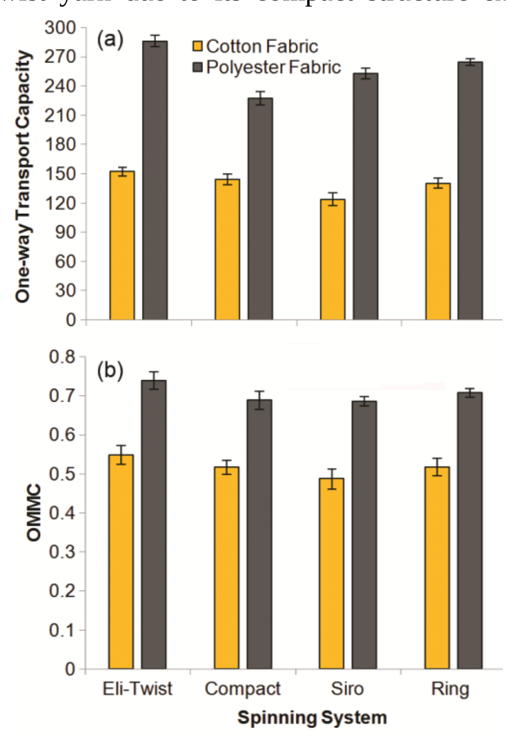

Fig. 4 — (a) Accumulative one-way transport capability of fabrics and (b) overall moisture management capacity (OMMC) of different knitted fabrics

Fig. 5 — Fingerprints of moisture management properties of different knitted fabrics

improved spreading speed as well as OWTC. OMMC takes care of rate of penetration (from top to bottom) followed by absorption and spreading of the liquid in the bottom surface. Quick transport and spreading has been good for moisture management.

The fingerprint of all the fabrics is shown in Fig. 5. Fabric has been ranked of 1-5 on the basis of moisture management parameters. Rank 1 indicates poor moisture management behaviour while rank 5 represents excellent moisture management fabric. The OMMC rank for polyester fabric made by all spinning system is found similar (rank-4) and for cotton knitted fabric it is Rank-3. The fingerprint of moisture management properties confers that cotton fabrics has similar grading while polyester fabric has a marginally better grading for their moisture management properties. The Eli-Twist fabric shows marginally better grading for its moisture management properties as compared to other fabrics.

4 Conclusion

In this investigation, an attempt has been made to study the moisture transport behaviour of polyester and cotton single jersey knitted fabric prepared from Eli-Twist, compact, ring and siroyarns. Moisture management behaviour of fabric has been determined through liquid moisture transmission characteristics. It is one of the most important comfort criteria, which determines the sweat absorption, its distribution and drying behaviour of fabric.

From the study, it is observed that single jersey knitted fabrics made from Eli-Twist yarns exhibit higher air and water vapour permeability followed by fabrics from compact, ring and siro yarns. The lower air and water vapour permeability is observed for cotton knitted fabric as compared to polyester knitted fabric.

The moisture transfer and quick drying behaviour of textile material depend mainly on the surface energy, capillary flow and regain of the constituent fibres. The drying behaviour of knitted fabrics made from Eli-Twist polyester yarns is found to be the highest as compared to that in fabrics made from compact, ring and siroyarns.

Moisture absorption capability, maximum wetted radius, spreading speed, accumulative one-way transport index (OWTC) and overall moisture management capacity index (OMMC) are found to be better for fabric preparedfrom Eli-Twist and ring yarn. However, all fabrics under study are graded as good to very good moisture management fabric.

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