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Influence of moisture management finish on comfort characteristics of knitted fabrics made from different yarns

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The influence of moisture management finish on comfort characteristics of knitted fabrics made from five different yarns has been studied in order to find out their level of performance. In order to study this effect, five types of yarns, namely microdenier polyester, spun polyester, polyester / cotton, filament polyester and 100% cotton, have been converted to knitted fabrics. It is observed that microdenier polyester fabrics having high wicking action and quicker moisture evaporation show superior performance with respect to comfort characteristics.

Keywords: Cotton, Filament polyester, Microdenier polyester, Moisture management finish, Polyester/cotton blend, Spun polyester

1 Introduction

It is well established that moisture management finished (MMF) microdenier polyester knitted fabrics have shown superior performance in comfort characteristics[1,2]. To know the level of performance of microdenier polyester as compared to other commercially available yarns, it becomes necessary to analyze the comfort characteristics of fabrics made from different yarns.

Wicking behaviour and drying rate are critical aspects for the performance of fabrics and have a practical significance in clothing comfort[3]. For comfort, the rate of evaporation should be as close to the wicking rate as possible. Liquid transfer mechanisms include water diffusion and capillary wicking, which are determined mainly by effective capillary pore distribution, pathways and surface characteristics, whereas the drying rate of a material is related to the macromolecular structure of the fibre, surface finish on fabrics and the amount of water absorbed[4]. In its unfinished state, polyester fibre is hydrophobic and has a much lower water absorption capacity than cotton fibre, but its wicking rate, although slow compared with some other synthetic fibres, is faster than that of cotton. Cotton fibres have perceived limitations with regard to apparel performance, since it is not considered ‘high-tech’, while polyester has high potential for ‘scientific creation’. When polyester is intended to make contact with the skin in a garment, it is usually chemically treated by hydrophilic polymer to improve its wicking ability. The hydrophilic polymer forms a durable polymer film that interacts readily with water imparting a hydrophilic finish. The resulting hydrophobic core and hydrophilic surface allow moisture to migrate along the outer surface of fibre without being absorbed into the core[5]. Knitted fabrics with smaller number of fabric contact points on the skin warranted by the uneven surface, results in reduced clinging sensation when the skin is sweat-wetted. The lesser the direct contact with skin, the greater is the wicking action. Fibre selection and chemical finishing are used to modify the performance characteristics of apparel fabrics to attain efficient moisture management[6]. Fabrics are often chemically treated for required applications, such as active wear, sportswear, outdoor clothing, work wear and intimate apparel in which the concept of moisture management is utilized to prevent or minimize the collection of liquid on the skin of the wearer due to perspiration.

In this investigation, the influence of moisture management finish on comfort characteristics of knitted fabrics made from different yarns have been studied, to know their level of performance. The

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comfort characteristics such as wetting, vertical wicking, transverse wicking, moisture vapour transfer and dyring rate are tested.

2 Materials and Methods

Five types of yarns, namely microdenier polyester (M1), spun polyester (M2), polyester/cotton blend (M3), filament polyester (M4) and 100% cotton (M5), were used for the study. Spun polyester, polyester/cotton and cotton were of 35^s count, whereas microdenier polyester (containing 108 filaments) and filament polyester (containing 34 filaments) were of 150 denier average fineness. The selected yarns were knitted on the circular knitting machine of 28 gauge to produce five different fabrics of single jersey plain structure containing 2.9 mm stitch length. All the test results were analysed using statistical tool at 95% confidence level and standard error has also been evaluated.

2.1 Finishing Treatment

Microdenier polyester, spun polyester and filament polyester fabric samples were first hot washed and then bleached. Cotton and polyester/cotton fabrics were first scoured and then bleached. All the five fabric samples were then coated with wetting agent (1gpl) and acetic acid (0.2gpL) for 15 min at 60º- 70º C temperature and 1:10 material-to-liquor ratio. After this wetting process, the fabrics were treated for moisture management finish (MMF). For this treatment, samples were treated with a dispersion containing a chemical combination of hydrophilic polysiloxane and hydrophilic polyester nonionic. The fabric samples were treated in the finishing bath using *p*H value of 5.5 at 60ºC – 70ºC for 10 min. The fabric samples were then dried and cured in a stenter at 150 ºC and subjected to relaxation for 48 h.

3 Results and Discussion

The influence of moisture management finish on comfort characteristics has been studied the findings are discussed hereunder.

3.1 Geometrical Characteristics

The geometrical characteristics of five different knitted fabrics have been measured and the average values of ten samples are taken (Table 1). The wale and course density of the fabrics are found increased after MMF is applied. The area shrinkage due to finishing treatment affects the areal density of the fabrics[7]. Microdenier polyester and filament polyester fabrics exhibit higher areal density and thickness than the other three fabrics. After MMF application, there is an increase of 7% in areal density and 9% in thickness for both fabrics. Spun polyester and polyester/cotton show 6% and 9% increase in areal density, while the increase in thickness is 2% and 4% respectively. Cotton exhibits a marginal 3% increase in areal density and 2% increase in thickness values. The application of MMF has reduced the loop length for all five fabrics, thereby showing an increase of 8.5% in stitch density.

3.2 Water Transmission characteristics

The water transmission characteristics of MMF knitted fabrics made from five different yarns have been analysed and the average values are taken (Table 2). It is found that the fabrics treated with moisture management finish exhibit better results in wetting, wicking and moisture vapor transfer as compared to untreated fabrics. All the fabrics show higher wicking length in wale-wise direction than in course-wise direction[8]. Fabrics made from filament yarns show superior results than the fabrics made from spun yarns.

Table 1 — Fabric geometrical characteristics

Material	Wales/ cm	Courses/ cm	Stitch density loops/cm^2	Areal density g/m^2	Stitch length mm	Thickness mm
Microdenier polyester						
Untreated	16.93	16.81	284.59	126	2.9	0.51
Treated	17.85	17.71	316.12	135.5	2.7	0.56
Spun polyester						
Untreated	16.53	14.96	247.28	106	2.9	0.44
Treated	17.32	15.74	272.61	113	2.8	0.45
Polyester/ cotton						
Untreated	16.28	15.02	244.52	100	2.9	0.41
Treated	17.13	15.56	266.54	110.5	2.8	0.43
Filament polyester						
Untreated	16.91	16.53	279.52	121	2.9	0.5
Treated	17.82	17.36	309.35	130.5	2.7	0.55
100% Cotton						
Untreated	16.89	16.45	277.84	122	2.9	0.44
Treated	17.66	17.28	305.16	126	2.8	0.45

Table 2 — Water transmission characteristics

Fabric	Sinking times		Vertical wicking (wicking height after 30 min), cm				Transverse wicking				Time taken to reach saturations		Moisture vapor transmission, %			
			Wales-wise		Course-wise		Water spreading area for 1mL of water cm^2		Area covered to reach saturation cm^2				Reduction in height of water		Reduction in weight of water	
	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated
Microdenier polyester	7.3	6.3	15.6	16.8	14.6	15.2	4.6	4.85	81.76	97.10	193	73	6.66	8.33	5.34	6.68
Spun polyester	16.6	10.6	4.5	12.9	4.0	9.7	2.6	3.85	27.94	68.58	210	100	4.69	5.83	3.74	4.66
Polyester/ Cotton	20.21	12.9	3.4	10.1	3.0	9.2	2.2	3.9	51.3	62.61	200	109	4.16	5.0	3.33	4.06
Filament polyester	14.6	10.3	13.5	14.6	12.2	13.1	4.4	4.65	68.58	88.3	154	74	5.83	6.66	4.68	5.36
100% cotton	16.0	9.8	11.9	14.2	9.6	12.1	4.2	4.6	74.93	83.95	200	83	5.83	6.66	4.66	5.34

3.3 Analysis of Wetting Characteristics

The ability of the fabric to sink completely in water has been tested and the findings are included in Table 2. It is observed that the microdenier polyester fabrics show the quickest wetting time followed by cotton and filament polyester fabrics. These fabrics take 36% more time to sink in water than microdenier polyester. Spun polyester takes 40% more time to sink in water, whereas polyester/cotton takes double the time to sink as compared to microdenier polyester fabrics. As compared to treated fabrics, the untreated spun polyester, filament polyester and cotton fabrics take 50% more time to sink in water. The untreated polyester/cotton fabrics take an unduly long time to sink in water but for microdenier polyester fabric it takes only 13% more time than treated fabrics. This is due to the finer filaments in its yarn cross - section.

3.4 Analysis of Wicking Characteristics

The rate of water spreading by capillary action is tested for wale-wise and course-wise direction (Figs 1 and 2). The wicking height of all five fabrics in wale-wise and course-wise directions are analyzed with respect to wicking time from 5 s to 5 min and upto 30 min. Figure 1 shows that the wicking length increases with time for all fabrics. The rate of increase is gradual for microdenier polyester, filament polyester and cotton fabrics, while it is very slow for spun polyester and polyester/cotton fabrics. Microdenier treated fabrics show 13% higher values than filament polyester and cotton fabrics. Except polyester/cotton, the other four fabrics show similar results after 1 minute. The wicking rate increases by 68 - 75% from 1 min to 5 min for microdenier polyester and filament polyester fabrics, while it is 60% for spun polyester and cotton fabrics. It is interesting to note that the wicking length attained in 5 s is 19 - 22% of total wicking length obtained in 30 min for microdenier polyester, spun polyester, filament polyester and cotton fabrics, while it is only 15% for polyester/cotton. But in untreated fabrics, microdenier polyester shows highest value followed by filament polyester and cotton. Spun polyester and polyester/cotton fabrics exhibit very low values. On comparing treated and untreated fabrics, it is clear that spun polyester and polyester/cotton fabrics show a very significant 3 times increase in wicking length for treated fabrics. This is due to the application of MMF on the fabrics. The effect of MMF is very significant for spun polyester and polyester/cotton fabrics.

As compared to untreated fabrics, the treated microdenier polyester and filament polyester fabrics show 7% increase in wicking length, while it is 16% for cotton fabrics. Filament fabrics exhibit higher wicking rates due to their inherent channeled fibre structures[9]. Channeled structures form a transport system that pulls moisture away from the skin to the outer layer of the fabric. These channels enhance water attraction into it because of hydrophilic surface treatment given by the MMF. Additionally microdenier polyester has a larger surface area due to the increase in inter fibre space in the yarn. This is due to more number of filaments in its yarn cross-section. Also the gap between the filaments inside the core of yarn is very less. This leads to higher wicking rate. Comparing spun fabrics, cotton with its good absorbency characteristics obtains higher wicking length. Cotton is easily wettable and does wick only when its capillaries are full. The initial wicking rate from 5 s to 1 min is higher in microdenier polyester and filament polyester fabrics which helps to pull the moisture away from skin to the outer surface of fabric. Spun polyester shows 22% higher wicking than polyester/cotton fabrics. This behaviour can be explained by absorption and wicking phenomena. Cotton is a highly hydrophilic fibre; it has good absorbency but due to its high affinity to water when water molecules reaches in the capillary, it forms a bond with absorbing group of fibre molecules, which inhibits the capillary flow along the channel formed by fibre surfaces. When blended with polyester the movement of water is partly governed by the absorption of water by the fibre and its movement along the fibre. This results in very less movement of water along the fabric. In spun polyester, the liquid surface is dragged very smoothly due to its positive contact angle (75º) which exhibits higher wicking than polyester/cotton.

The same trend was observed by Das *et al.*[10]. Among polyester fabrics, filament polyester show higher wicking than spun polyester due to continuous filaments in its yarn, which allows the capillary to rise unhindered. Figure 2 shows that the wicking rate for course-wise follows a similar trend as in wale-wise direction. As compared to wale-wise, the total wicking length after 30 min is less by 9 - 10% for filament fabrics, 25% for spun polyester and 15% for cotton. For polyester/cotton fabrics, the reduction is 9%, Similarly the wicking length is lesser at all time intervals. The reason for this is, water moves longitudinally faster in vertical direction because knit loops lie one above the other and the loop leg orientation of the yarn is in wale-wise direction, while in course-wise direction the loops are set side by side where the movement of water follows the loop; i.e. first in horizontal direction and then in vertical direction intermittently. So capillaries are easily formed in wale-wise direction but along the courses

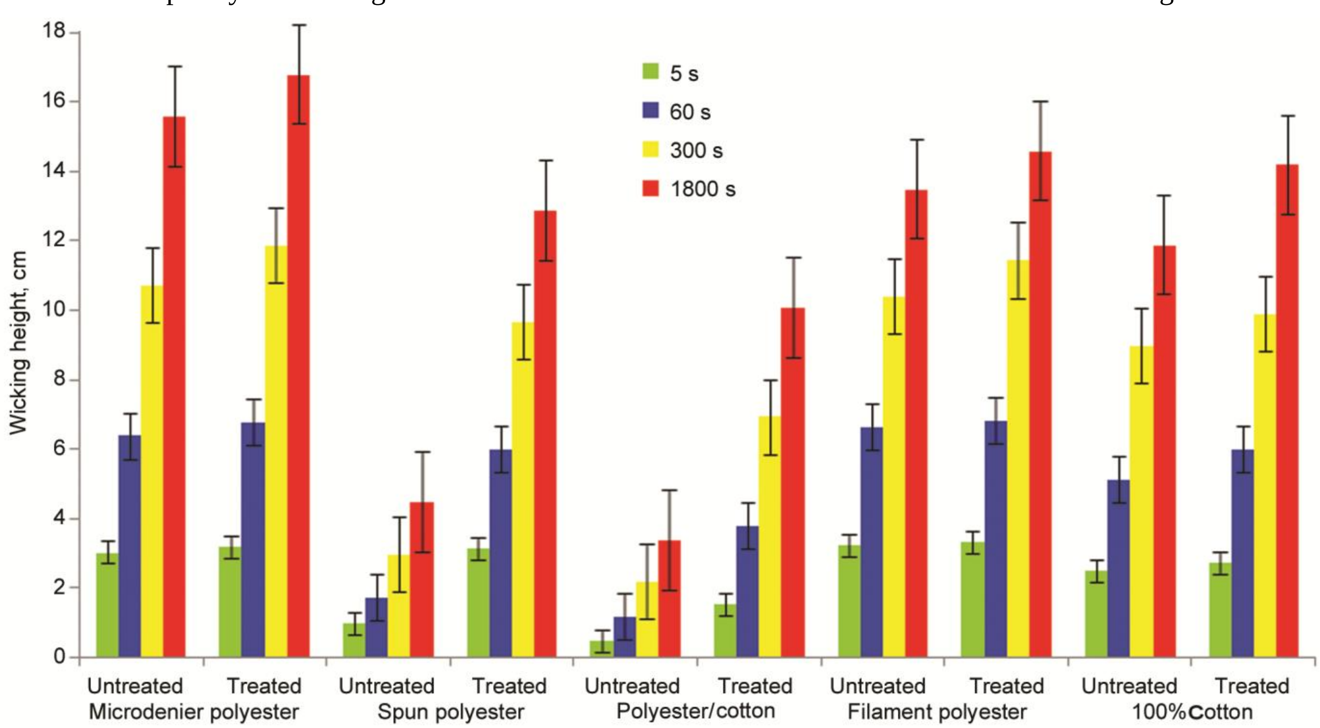

Fig. 1 — Vertical wicking of fabrics in wale-wise direction

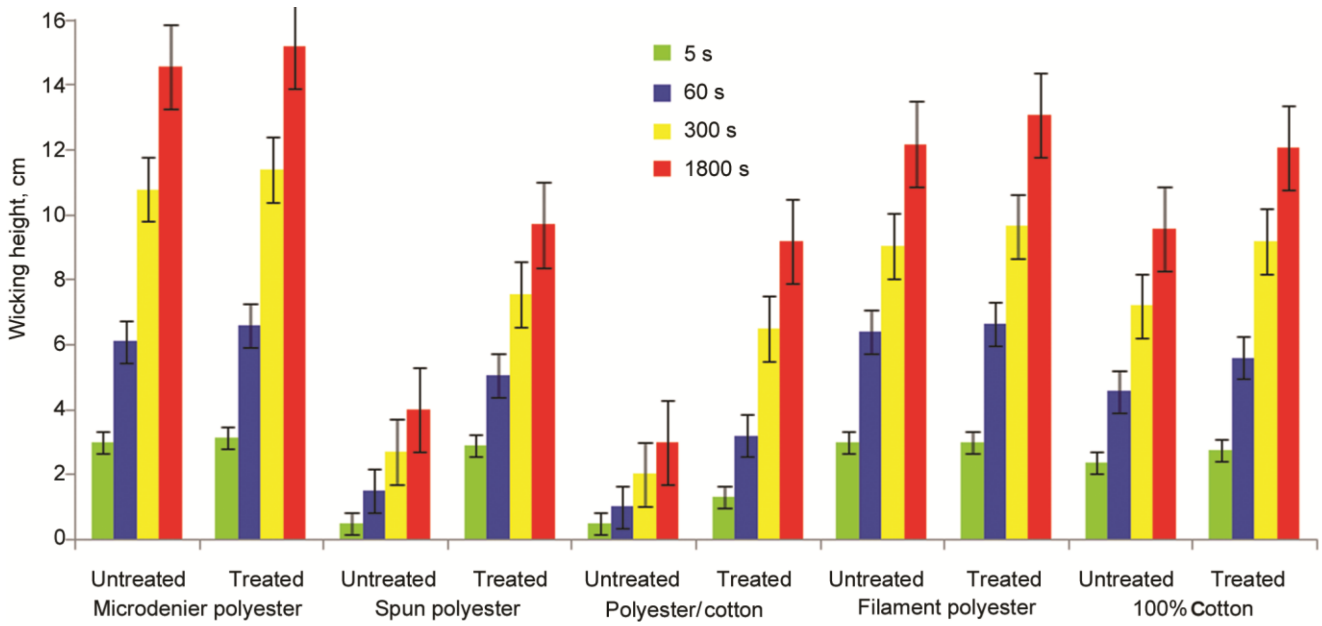

Fig. 2 — Vertical wicking of the fabrics course-wise direction

there is a hindrance to water movement. The same trend is observed by Patil *et al.*[11] on different materials under different conditions. Interestingly, as compared to untreated fabrics, the treated fabrics show 4 - 7% higher wicking for filament fabrics, while it is 2.5 times higher in spun polyester and 3 times higher in polyester/cotton fabrics. These results follow a similar trend as in wale-wise direction.

3.5 Analysis of Transverse Wicking Characteristics

The area covered by the spreading action of water for one drop and saturation method is discussed hereunder.

3.5.1 Area of Water Spread for One Drop of Water

The area covered by the spreading action of one drop (1mL) of water has been studied and findings are included in Table 2. It is seen that microdenier polyester fabrics show higher spreading area followed by filament polyester and cotton fabrics. But the difference is only marginal. Spun polyester and polyester/cotton fabrics show lower spreading area. Transfer wicking is a unique phenomenon with respect to water transfer behaviour of fabrics, since it has no directional effect. When the area spread is more the evaporation of the fabric is also more. In filament fabrics, the spaces between the fibres create more capillaries with larger area spread and quicker moisture evaporation. Compared to treated fabrics, the untreated fabrics show 32 - 44% lower area spread for spun polyester and polyester cotton respectively. Filament fabrics show 5% lower area while it is 9% for cotton. The application of MMF has increased the area spread for spun polyester and polyester cotton fabrics.

3.5.2 Area of Water Spread and Time Taken to Reach Saturation

The area covered and time taken to reach saturation point has also been studied (Table 2). It is observed that the water spreading area (to reach saturation) is larger area for microdenier polyester and filament polyester fabrics followed by cotton. Spun polyester and polyester/cotton exhibit 30% lesser area spread to reach saturation point. The MMF treatment of spun polyester and polyester/ cotton fabrics noticeably increases the rate of liquid water absorption (wicking), but does not affect the total amount of water absorbed by the fabric or its water vapor absorption, since MMF alters only the hydrophilicity of the fabric surface. The absorption of water by the fibre molecules as well as the moisture fill up in the inter-fibre and inter-yarn pores of the fabric decide the area spread. Spreading of the water reduces troughs of low thermal resistance areas in the fabric. This is decided by the number of hydrophilic groups in the fabric. On the other hand, the amount of water taken up by the pores will be dependent on the porosity of the material. Here, the stitch density of the fabrics is nearly similar, so all materials are having same porosity. Hence, absorption and spreading are due to the hydrophilic group in the fabric. The MMF has provided the hydrophilic capacity. Additionally, filament fabrics have higher surface tension which helps to hold the water droplet and transfer it in the lateral direction against gravitational force. More inter-fibre space in the fabric ensures that the water spreads well in parallel along the fabric plane. The advantage of these assessments is that since transverse wicking being multi-dimensional, it eliminates the directional effect. The effect of MMF is very significant with respect to area spread and time taken.

3.6 Analysis of Moisture Vapour Transfer Behaviour

The rate at which moisture vapor moves through a fabric has been tested and findings are shown in Table 2. It is seen that the microdenier polyester exhibits higher moisture vapour transfer (MVT) rates than the other four fabrics. Filament polyester and cotton fabrics show 20% lower MVT than microdenier polyester fabrics. Spun polyester and polyester/cotton fabrics shows 30% and 40% lower MVT than microdenier polyester fabrics. Microdenier polyester consisting of finer filaments in its yarn transfers more moisture through the fabric within the given time. Filament polyester fabrics have similar thickness and stitch density values of microdenier polyester but gives 20% lower MVT. This is due to the coarser filaments in its yarn cross- section for the same diameter. The lower MVT rates of spun polyester and polyester/cotton fabrics may be due to the fabric surface hairiness which partly hinders moisture transmission. Compared to untreated fabrics, the treated fabrics show 17 - 20% higher height and weight reduction. The application of MMF has increased the MVT rates for all give fabrics.

3.7 Drying Characteristics

The quick drying capability of the five different fabrics have been evaluated by their drying rate. It indicates the ability of the fabric to evaporate the moisture present. Figures 3 (a) and (b) show that wicking ability and MMF play an important role in the drying capability of the fabrics. Microdenier polyester fabrics show the quickest drying time followed by filament polyester. This is due to the finer filaments in the yarn which gives greater exposed surface area thus facilitating faster drying of the fabrics. A similar trend is also noticed by Srinivasan *et al*[1]. Spun polyester, polyester/cotton and cotton fabrics take 14% longer time to dry completely than microdenier polyester. Filament fabrics exhibit quicker drying time than the spun fabrics. This is because filament fabrics have inherent channeled

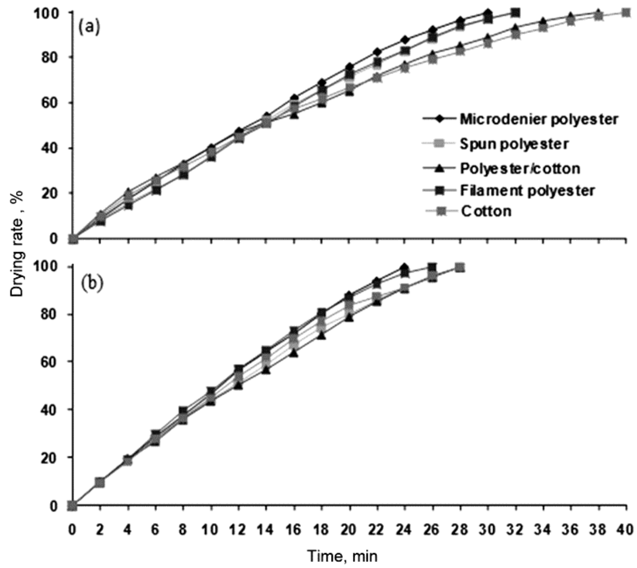

Fig. 3 — Drying rate for (a) untreated fabrics and (b) treated fabrics

fibre structures due to the stiffness of its yarns. Also the channels are continuous, thus facilitating effective water transport and subsequent evaporation. This increases the drying rate of filament fabrics. The same trend is also observed by Miller and Cravotta[12]. It appears that the drying capability of the fabrics is related to the macromolecular structure of its fibres.

Compared to untreated fabrics, the treated fabrics show quicker drying rates. Microdenier polyester & filament polyester exhibited 20% faster drying rates while for spun polyester it is found 12%. Polyester / cotton and cotton fabrics exhibit 26% and 30% faster drying rates respectively. The untreated polyester/cotton and cotton fabrics took a longer time to dry than the other three fabrics. This is due to the fact that cotton fibre swells when absorbing water and subsequently takes a longer time to dry. The application of MMF is significant with respect to drying rate.

4 Conclusion

4.1 In the wetting test, microdenier polyester fabrics show the quickest sinking time. Cotton and filament polyester fabrics take 36% more time to sink in water than microdenier polyester. Spun polyester takes 40% more time to sink in water, whereas polyester/cotton has taken double the time to sink when compared to microdenier polyester fabrics. Compared to treated fabrics the untreated spun polyester, filament polyester and cotton fabrics show 50% more time to sink in water.

4.2 In the wicking test, the wicking rate increases in the range of 68 - 75% during the 1 - 5 min for microdenier polyester and filament polyester fabrics, while it is 60% for spun polyester and cotton fabrics. The wicking length attained in 5 s is found 19 - 22% of total wicking length obtained in 30 min for microdenier polyester, spun polyester, filament polyester and cotton fabrics, while it is only 15% for polyester/cotton fabrics. Comparing to untreated fabrics it is clear that the treated spun polyester and polyester/cotton fabrics show a very significant (3 times) increase in wicking length. The treated microdenier polyester and filament polyester fabrics show 7% increase in wicking length, while it is 16% for cotton fabrics. Compared to wale-wise direction, the total wicking length after 30 min for course-wise direction fabrics is less by 9 - 10% for filament fabrics, 25% for spun polyester and 15% for cotton fabrics. For polyester/cotton fabrics the reduction is 9%. Compared to untreated fabrics, the treated fabrics show 4 - 7% higher wicking for filament fabrics, while it is 2.5 times higher in spun polyester and 3 times higher in polyester/cotton fabrics.

4.3 In the transverse wicking test for one drop of water, microdenier polyester fabrics show higher water spreading area followed by filament polyester and cotton fabrics. Spun polyester and polyester/cotton fabrics show lower spreading area. Compared to treated fabrics, the untreated fabrics show 32 - 44% lower area spread for spun polyester and polyester cotton respectively. Filament fabrics show 5% lower area spread, while it is 9% for cotton fabrics. In the saturation test, the water spreading area is found larger for microdenier polyester and filament polyester fabrics followed by cotton. Spun polyester, polyester/cotton and cotton exhibit 30% lesser area spread to reach saturation point. The time taken to reach saturation point for untreated fabrics of microdenier polyester, filament polyester, spun polyester and polyester/cotton is nearly 2 times more than that of treated fabrics.

4.4 In the MVT test for reduction in height and weight of water, filament polyester and cotton fabrics show 20% lower moisture vapour transfer than microdenier polyester fabrics. Spun polyester and polyester/cotton fabrics show 30% and 40% lower MVT than microdenier polyester fabrics respectively. Compared to untreated fabrics, the treated fabrics show 17 - 20% higher MVT. In the drying rate test, microdenier polyester fabrics show the quickest drying time of 24 min followed by filament polyester with 26 min. Spun polyester, polyester/cotton and cotton fabrics take 14% longer time to dry completely than microdenier polyester. Compared to untreated fabrics, the treated microdenier polyester and filament polyester fabrics exhibit 20% faster drying rates, while for spun polyester it is 12%. Polyester / cotton and cotton fabrics exhibit 26% and 30% faster drying rates respectively. Comparing all selected fabrics, it is concluded that microdenier polyester fabrics with its high wicking action and quicker moisture evaporation has given a superior performance in comfort characteristics.

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