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Influence of Moisture Management Properties on Socks Made from Recycled Polyester, Virgin Cotton and its Blends

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Abstract
The moisture management properties of socks made from recycled polyester, virgin cotton and its blends were studied and compared. As an outcome of this research, the OMMC (Overall Moisture Management Capacity) of socks produced from recycled polyester fabrics gave higher values than those of virgin cotton fabrics. This result demonstrates that recycled polyester fabrics have good moisture management properties and faster water transport capacity compared to other fabrics. The lowest OMMC values were observed for virgin cotton fabrics.

Key words: *comfort, moisture management, recycled polyester, virgin cotton, recycled polyester/virgin cotton blend.*

Introduction

The human body is an intricate framework that is in harmony with its environment while acting out its essential capacities appropriately. For individuals heat is created rapidly in the body during exercise, running, walking, working as well as resting. The increase in body temperature increases the sweat rate. Generally, sweat begins to discharge the cooling arrangement of the body to eliminate surplus heat created in the body. At the point when the perspiration dissipates from the skin or fabric texture surface, water vapour conveys this excess heat, as a result of which, the comfort status of the body is secured [15, 20]. Socks have the dual purpose of acting as external apparel and shielding from the cold. Socks are one of the accessory items that have a minimal life among garment merchandise since they can be produced at a lower cost than other material items and are widely consumed and utilised for style and basic needs by humans [9]. Also, less airflow occurs in socks enclosed in shoes than in pieces of clothing on different parts of the body. There are not many studies related to the comfort of socks, which are skin-tight garments of clothing [5, 9, 28]. The aim of this study was to partially fill this gap by doing an in-depth analysis of the comfort properties of socks. Generally, the quality of socks can vary depending on many factors: their type, the properties of yarn used, knitting conditions, machine parameters, finishing method.

Consumer loyalty has become important, and customers have turned out to be increasingly mindful of their requirements by looking for items of progressively quality. This causes customers to desire to get more information about socks, and therefore they should be designed to meet customer loyalty following fashion and functional needs. Likewise, the performance of socks should satisfy customer requirements, and also the fibre blend should not affect consumer health negatively [27]. Simultaneously, socks should have flexibility, thermo-physiological comfort and protection from wear and tear. It means giving ideal warmth, dampness, and airflow. Avci. H [1] investigated the physical and comfort aspects of socks knitted from cotton, modal, viscose, bamboo, seacell and soy yarns. The testing of water vapour conductivity demonstrated that viscose gave the fewest qualities, while bamboo-cotton and seacell gave the best results. As for thermal resistance findings, modal and soy gave the most minimal. Cimilli [8] researched socks with three distinct densities of new strands like modal, micro-modal, bamboo, soy and chitosan. He concluded that the most worn example was micro-modal. Cotton had the most minimal air-penetrability, while modal samples had the highest values. Modal samples also gave higher dampness recuperation results. Cotton samples had the most noteworthy values for warm conduction and convection.

A lot of different kinds of textile wastes are disposed by both the textile industry and humans annually. Textile waste which consists of by-product materials in the form of fibre, yarn, and fabric is known as pre-consumer waste. As a virgin fibre, the most usually preferred kinds are cotton and polyester. The fibre type utilised as virgin fibre and the extent of it in the yarn is, for the most part, decided by the waste type and yarn count. At the point when recovered filaments are acquired from fabric scraps, virgin polyester fibre is economically more favoured than virgin cotton fibre in mixing. The mixing of reclaimed fibre with virgin polyester fibre builds the tenacity of the resultant yarn because of the high fibre strength property of polyester fibre. Halimi et al. [13, 14] expressed that fibres acquired from textile material wastes can be mixed with virgin cotton up to 20% without recognisable changes in yarn quality. Necef, Seventekin, and Pamuk [17] examined the convenience of recycled garments of clothing derived from fabric texture scraps. For the production of single jersey knitted fabrics and garments, 50% recycled cotton – 50% polyester and 50% virgin cotton – 50% polyester yarns were used. The investigation proposed that garments derived from fabric scraps could be utilised in the apparel industry.

In another study about fabrics made from reclaimed fibres, the physical properties of socks produced from a blend of reclaimed cotton/virgin polyester fibres were compared with those of 100% virgin cotton fibres, considering the influence of combined elastane [12]. The reclaimed fibre socks proved to have lower air permeability and a higher stitch density, mass, thickness and pilling tendency than virgin cotton socks. From the outcome, it was inferred that just as virgin cotton fibre, recycled fibre could be utilised in the manufacture of socks of satisfactory quality by mixing it with virgin polyester fibre. Moisture management is a fundamental component of a textile material regarding its comfort appeal. Mixing and blending also have a vital role in the moisture-related capability of a textile material. The presence of liquid particles on the skin, whether they come out of the body or are taken from outside, is accepted as a less healthy and comfortable state [3, 4, 11, 30].

To have health conditions and himidity comfort, the liquid particles on the body must be absorbed by the inward substance of the fabric before they contact it, at which point they be will driven outside of the external substance of the fabric texture, and afterwards they should vanish [19]. To actuate vanishing rapidly, the liquid must spread to the external side of the fabric at the top-level [29]. The moisture transport properties of garments have an incredible effect on the thermal comfort of the body [4, 7]. Moisture management test results of samples indicate that fabrics produced from recycled polyester yarns show very low one-way transport capability. Synthetic fibres can absorb a relatively small amount of moisture because of their hydrophobic character, which causes poor wettability [11]. The moisture management properties of a fabric decide the individual's comfort perception, depending on the response between the human body and external conditions. In light of this, several test methods and pieces of equipment were used by various researchers and the moisture management properties of fabrics analysed [18, 21, 22]. Hu, Li, Yeung, Wong & Xu [15] developed a moisture management tester (MMT) which measures the liquid moisture transport performance multi-dimensionally for both knitted and woven fabrics. The present study analysed the moisture management properties of socks made from recycled polyester/ virgin cotton and its blends.

Materials and methods

The effect of moisture management properties on socks made from recycled polyester fibres, virgin cotton fibres, and its blends was studied. To analyse this effect, recycled polyester fibres, virgin cotton fibres and their blends were converted to yarn on a Lakshmi Rieter G5/1 ring frame (Lakshmi Machine Works Ltd. (LMW), India) with a count 30 s Ne. Five different blends of socks were produced on an AE18 model, fine 3-inch (76 mm) dia electronic plated Lonati knitting machine (Lonati, Italy). All the socks were knitted on the same machine, keeping the machine parameters the same and a similar stitch length of 3 mm. The structure of the socks for all the fabrics was the same, namely single jersey. The socks were subjected to relaxation for 48 hours, after which it was conditioned at 22 °C and 65% RH standard conditions.

Moisture management measurments

Sock samples were prepared and tested for moisture management properties as per AATCC 195-2009 standards (Liquid Moisture Management Features of Textile Fabrics), using an MMT M290 testing device, produced by SDL Atlas, USA.

Results and discussion

Physical properties of the socks were measured, the average values of which are given in ***Table 1***.

From ***Table 1***, it is seen that the areal density and fabric thickness increase with an increase in the virgin cotton content in the blend.

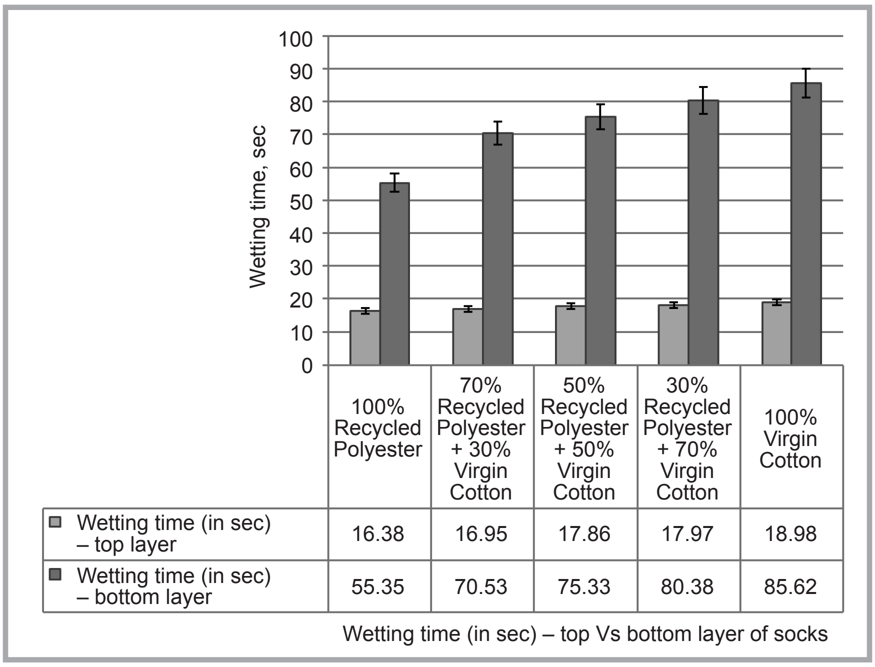

Figure 1. *Wetting time (in sec) of sock fabrics – recycled polyester/virgin cotton and its blends.*

Analysis of wetting properties

Wetting time is the time taken to initiate wetness on the top and bottom layer of the test sample. The top (WTt) and base (WTb) wetting time show the time taken by liquid to wet the internal (besides skin) and external layers of the fabric as the test is initiated. The top surface of the fabric means the initial surface in which a test-water drop comes in contact with the skin of the wearer [29]. In ***Figure 1***, the fabric wetting time (in seconds) of the top and bottom layers is given. From ***Figure 1***, it can be seen that water content present on the top layer of the fabric is lower than that on the bottom layer, thus indicating a quick transfer of water from the top to the bottom for all fabrics. It is noticed that the variations in the blend ratio results change with the wetting time for both the top and bottom layer of the fabrics. Comparatively, a bottom layer of 100% virgin cotton fabrics results in the slowest wetting time, because the virgin cotton absorbed water rapidly and

Table 1. *Physical properties of sock fabrics – recycled polyester/ virgin cotton and its blends.*

S.No.	Fabric	Wales, cm	Courses, cm	Areal density, g/m^2	Fabric thickness, mm
1	100% Recycled Polyester	18	20	142.23	0.521
2	70% Recycled Polyester 30% Virgin Cotton	18	20	155.32	0.593
3	50% Recycled Polyester 50% Virgin Cotton	17	21	165.21	0.611
4	30% Recycled Polyester 70% Virgin Cotton	17	22	173.32	0.629
5	100% Virgin Cotton	16	22	180.23	0.652

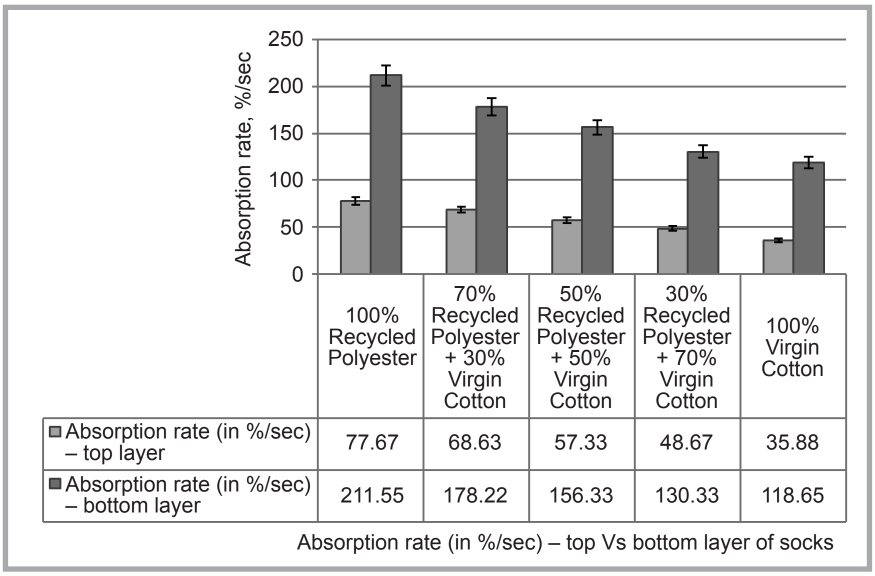

Figure 2. *Absorption rate (%/sec) of sock fabrics – recycled polyester/virgin cotton and its blends.*

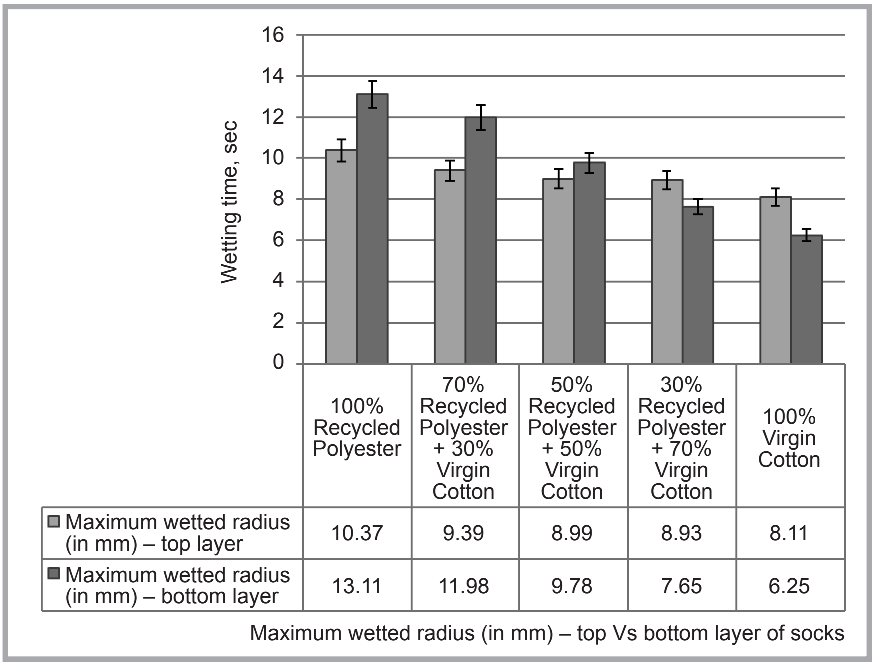

Figure 3. *Maximum wetted radius (mm) of sock fabrics – recycled polyester/virgin cotton and its blends.*

transferred it to the bottom surface very slowly. It is seen that both 100% recycled polyester and 70:30 recycled polyester/virgin cotton fabrics results in the fastest wetting time for both the top and bottom layer of the fabric. Subsequently, a higher content of recycled polyester results in a lower wetting time. Also, as the recycled polyester content increases, the fabric thickness decreases. Prakash, Ramakrishnan, Chinnadurai, Vignesh and Senthilkumar [6] expressed that thinner fabrics show faster wetting than thicker ones when equal amounts of water are applied. From ***Figure 1***, it is noticed that in recycled polyester fabrics, the wetting time is very low compared with recycled polyester/virgin cotton blend fabrics, since water is transported through the layers of fabrics very quickly due to the hydrophobic nature and wicking capability of recycled polyester fibre. In the case of 30:70 recycled polyester/virgin cotton fabrics, the wetting time is marginally higher than for 100% recycled polyester fabrics. This is due to water being stored in the top layer and the resultant slower moisture transfer to the bottom layer, which may due to the water absorbency characteristics of virgin cotton fibres.

Cotton fibres have a hydrophilic property, with speaces for water particles to be retained. Hence, water tends to get retained by the hydrophilic fibres, which have poor moisture transportation properties when compared with hydrophobic recycled polyester fibres [24]. From ***Figure 1***, it is seen that the water content of the bottom surface is higher than that of the top surface in all fabrics, which ensures the liquid is transferred effectively from the inner surface to the outer surface of the fabric. The faster transfer of water by recycled polyester fibre takes place compared with recycled polyester/virgin cotton blends because recycled polyester is hydrophobic with very low moisture regain properties. 100% virgin cotton has a very slow wetting time both at the top and bottom surfaces, as these are hydrophilic fibres with high moisture regain.

Analysis of absorption properties

The rate of water absorption by socks is defined by the average speed at which the test-water drop is absorbed by their top layer after initial wetting. The absorption rate is related to the tendency of the fabric to allow the slippage of water through the inter-yarn, inter-fibre and intra-fibre spaces. The absorption value is the amount of maximum absorption that the fabric has got in the dripping period of the testing solution on the fabric [16]. The absorption rates of recycled polyester/virgin cotton blended fabrics for both the top and bottom layer are given in ***Figure 2***. It is seen that the absorption rates are dependent on the fibre and its blends. An increase in the recycled polyester content in the blend gives a higher absorption rate. As observed in ***Table 1***, an increase in the recycled polyester content results in a decrease in the fabric thickness. Generally, the absorption rate is greater for thinner fabrics. The rate of absorption of the bottom layer fabric shows better results than the top layer, showing that the bottom layer of the fabric tends to spread the maximum amount of liquid moisture. The absorption rate of 100% recycled polyester fabrics shows better results for the bottom layer, thus transporting the liquid from the top layer to the bottom layer very quickly, where the liquid gets accumulated in the bottom layer. The reason for the lower absorption rate on the bottom surface in the samples having virgin cotton fibre is that the liquid moisture is greatly absorbed on the top surface, and because of this it is transferred to the bottom less.

Analysis of maximum wetted radius properties

The maximum wetted radius test results are given in ***Figure 3***. To meet the highest moisture comfort conditions, liquid transmission properties should be fast in the inner layer of socks and less in the outer layer to give rapid evaporation. From ***Figure 3*** it is observed that the maximum wetted radius of recycled polyester fabrics gave excellent results, thereby easily transporting the liquid sweat to a large area due to capillary forces. When the sweat gets evaporated from the skin surface, the body experiences a loss of heat, therefore the instant heat loss of liquid sweat increases the cool and sweaty feeling of the wearer. Hence, to avoid a cool feeling, a fabric that has a good capillary effect can be useful to take sweat away from the skin surface. Therefore, a lower top MWR value denotes lower wet touch and higher skin comfort [3, 23]. In blended fabrics, recycled polyester/virgin cotton blends show a large wetted radius on the top and bottom surface with an increase in the recycled polyester content. An increased content of recycled polyester in the blend results in a larger MWR due to its hydrophobic nature. Because of this characteristic of recycled polyester, water molecules were either not absorbed or only a small quantity of moisture could be.

Analysis of spreading speed properties

The spreading speed is essential in determining the drying ability of fabric, as the fabric can spread the liquid over large areas to facilitate liquid evaporation to the environment. In general, spreading speed is defined as the accumulated spreading speed from the centre of the top (there is spreading for both the top and bottom layer of fabric (SSt) towards the top layer of the maximum wetted radius (MWRt). ***Figure 4*** shows the spreading speed at the top (SSt) and bottom (SSb) surfaces of recycled polyester/virgin cotton blended fabrics. From ***Figure 4***, recycled polyester fabric shows the highest value for the top and bottom spreading speed, suggesting that the fabric provides a large spreading area for liquid evaporation, and hence it would dry quickly. This may be attributed to the lower fabric thickness and wetting time. the lower values of the spreading speed of the top and bottom for the other four fabrics may be attributed to their higher wetting time. The more time the fabric takes to wet, the lower its spreading speed, and hence such fabrics would take longer to dry. A comparison between 100% recycled polyester and recycled polyester/virgin cotton fabrics demonstrates that a higher content of recycled polyester in the blend improves the spreading speed of the top and bottom surfaces, giving better performance and, hence, making these blends more suitable for sports garments. The spreading speed of recycled polyester/virgin cotton fabrics was found to be much higher than that of 100% virgin cotton fabric.

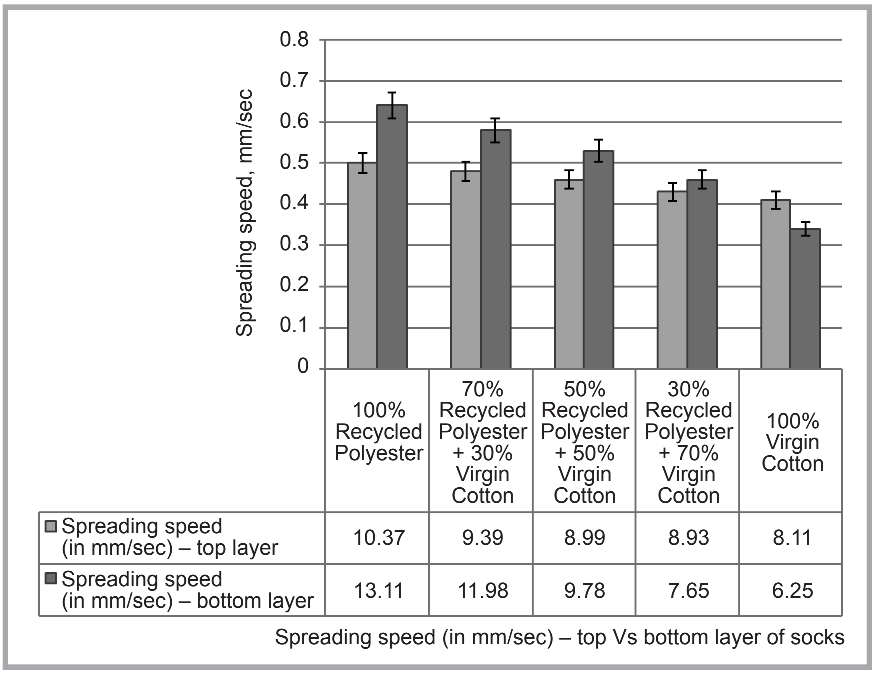

Figure 4. *Spreading speed (mm/sec) of sock fabrics – recycled polyester/virgin cotton and its blends.*

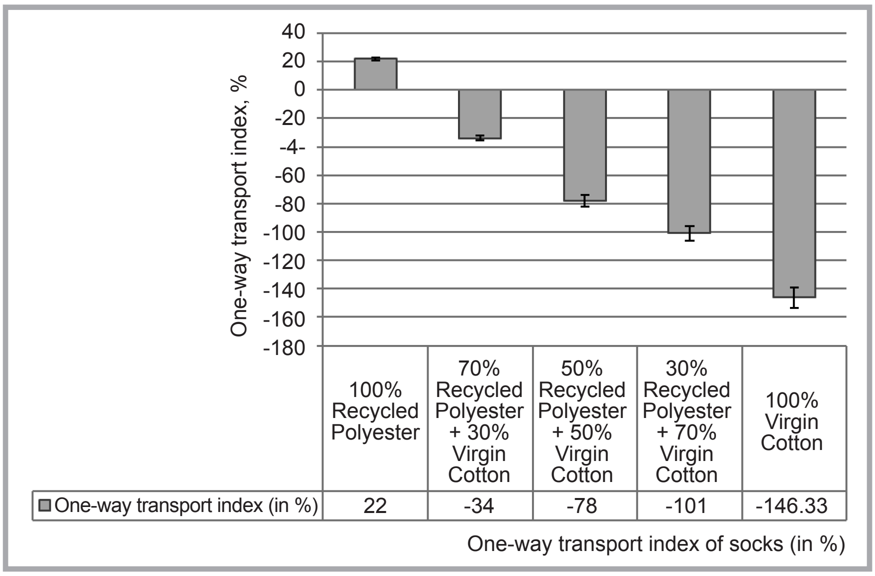

Figure 5. *Accumulative one-way transport index (AOTI %) of sock fabrics – recycled polyester/virgin cotton and its blends.*

Analysis of Accumulative One-way Transport Index (AOTI)

The value of the Accumulative One-way Transport Index (AOTI) is a parameter which represents the dissimilarity between both the top and bottom sides of the fabric. It indicates the mean grade of the accumulative one-way transport index for the five fabrics. When the AOTI results were examined, the 100% recycled polyester fabrics were found to have significantly higher values than the other fabrics. The AOTI results of virgin cotton

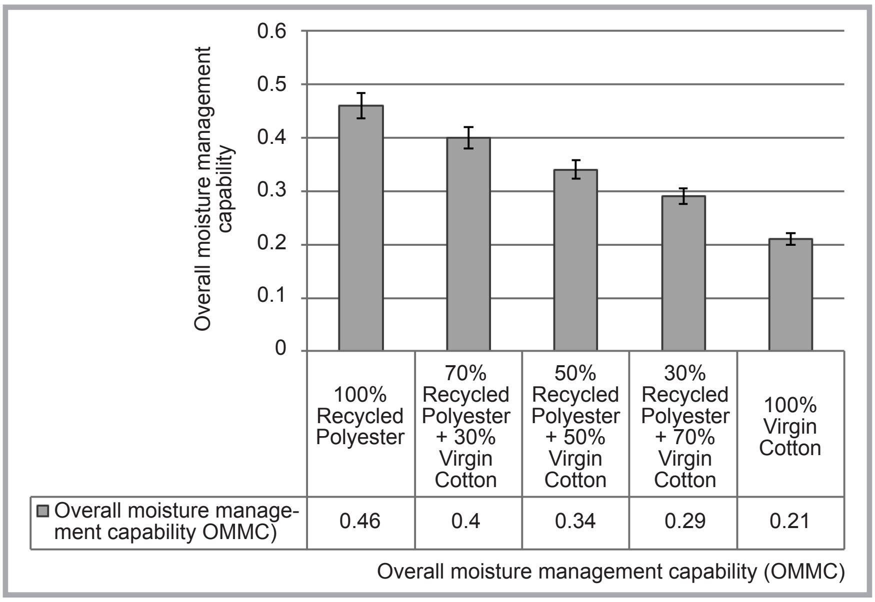

Figure 6. *Overall moisture management capability of sock fabrics – recycled polyester/ virgin cotton and its blends.*

fabrics were found to be negative since they hold liquid sweat in their structure and, hence, keep the wearer with a wet feel. Overall, the positive AOTI results indicate that liquid sweat can be easily transported from the skin (inner layer) to the outer layer very quickly. Alternatively, the negative AOTI results indicate that liquid sweat was transported from the skin (inner layer) to the outer layer slowly and spread gradually in lesser wetted areas. From ***Figure 5***, it is observed that the values of 100% recycled polyester and recycled polyester/virgin cotton fabrics are higher than those of virgin cotton fabrics. Recycled polyester/virgin cotton fabrics show an excellent one-way transport index grade, whereas virgin cotton fabric shows the least one-way transport index grade. Comparing 100% recycled polyester fabric with recycled polyester/ virgin cotton fabrics, it can be seen that the more the recycled polyester content in the blend, the higher the AOTI value, making it more suitable for sportswear and its applications.

Analysis of Overall Moisture Management Capability (OMMC)

From ***Figure 6***, it is seen that 100% recycled polyester gave higher OMMC values, followed by 70:30% recycled polyester/ virgin cotton blend fabrics. The higher the virgin cotton content in the blend, the lower the values. A similar trend was also seen for all the other test results. Comparing 100% recycled polyester fabric with recycled polyester/virgin cotton blend fabrics, it is seen that an increase in the recycled polyester content in the blend improves the OMMC values significantly, indicating that blending virgin cotton with recycled polyester is more suitable for sportswear application. The same results were observed in the One Way-Transport Index grade values for 70:30 recycled polyester/virgin cotton fabrics, which means that the fabric can transmit sweat to the outer side much faster.

For synthetic fibres, liquid moisture transport mainly depends on the capillary of their structure. Also, it is known that a decrease in the capillary radius generates higher pressure, which provides faster flow through the capillary (Babu SB, Senthilkumar P and Senthilkumar M 2015). Owing to the higher capillary of recycled polyester fibres, water can be easily transferred through the surface by capillary forces. This result demonstrates that these fabrics can easily transfer sweat generated after any activity while keeping a dry feeling for the wearer. Besides, recycled polyester fabrics have also shown adequate transport properties (***Figure 6***), whereas because of the hydrophilic character of virgin cotton, it has a lower moisture management capability, due to the higher moisture absorption capacity of these fibres. The same is in the case of recycled polyester/virgin cotton blends: increasing the hygroscopic content in the blend increases moisture absorption and results in faster drying of sweat from the skin [10, 26].

Conclusions

The blending of textile fibres in the manufacture of socks plays an important role in the moisture management properties of clothing. This research work mainly focused on the influence of fibre blend ratios on the moisture management properties of recycled polyester/virgin cotton socks. Ultimately, the fibre type's blend ratio and fabric thickness influence the moisture management properties of socks significantly. The benefit of using recycled polyester and its blends in socks is their better moisture management properties (AOTI and OMMC results). Considering the global sustainability factors, recycled polyester has been used in socks and has also proved to have excellent moisture management properties. This result clearly shows that 100% recycled polyester fabrics can transfer liquid sweat from the inner layer to the outer layer very quickly. In recycled polyester fabrics, liquid sweat is not absorbed because of its hydrophobic characteristics, thus maintaining the wetness feeling of the wearer by transporting the liquid sweat quickly. Finally, it is concluded that 100% recycled polyester is more suitable for the end-use of socks. It is also suggested that a 70:30% recycled polyester/virgin cotton blend has convincing moisture management properties. The higher blend ratio of recycled polyester leads to the best overall performance of moisture management, thereby vastly improving the comfort properties of socks.

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