Indian Journal of Fibre & Textile Research
Vol. 34, December 2009, pp. 315-320

Moisture management performance of functional yarns based on wool fibres

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Received 16 October 2008; revised received and accepted 4 March 2009

Blends of wool and moisture management fibres such as Coolmax and Finecool have been prepared to produce innovative yarns with specific functionalities. These yarns have been used to produce knitted fabrics and their performance is evaluated, including vertical and horizontal wicking. The drying capability of the fabrics has been assessed by drying rate testing under two different conditions, namely standard conditions (20±2ºC and 65±3 % RH) and, in an oven at 33±2ºC to simulate the body skin temperature. The influence of wool fibre proportion on the performance of each blend is analyzed. It is observed that the Coolmax based fabrics show the best capillarity performance, and the wool based fabrics show low water absorption performance but good drying rate.

Keywords: Coolmax fibre, Drying capability, Finecool fibre, Functional yarns, Wicking performance, Wool

1 Introduction

Wool remains a premium apparel fibre with an impressive set of technical attributes. For carpets and rugs, wool remains the benchmark of quality and performance with which other fibres are compared[1].

The unique physical and chemical structures of wool create a range of natural characteristics that have been proved ideal for apparel, upholstery fabrics and carpets[2]. These characteristics are warmth and coolness, breathability, moisture absorption and buffering, resilience, low odour, odour absorption, softness, flame resistance, biodegradability and recyclability, resistance to soiling and staining[2]. These special characteristics of wool can be exploited in a worsted suit or knitted outerwear or enhanced to create novel apparel fabrics. Wool is increasingly being used in technical applications in which its unique properties and the opportunities for specific enhancements can be profitably utilised[1].

The versatility of wool has been demonstrated by a number of innovative apparel products entering the sportswear marketplace. These products, which combine different fibres and structures, include the Icebreaker and SportWool ranges. Icebreaker uses fine merino wool for comfort and warmth in outerwear, mid-layer, and underwear garments, while SportWool combines the best features of wool and polyester fibres in a bi-layer fabric, suitable for highly active sports. Both products involve the use of technical data to demonstrate the benefits they offer to the wearer[1].

Liquid transporting and drying rate of fabrics are two vital factors affecting the physiological comfort of garments[3-5]. The moisture transfer and quick drying behaviour of textiles depend mainly on the capillary capability and moisture absorbency of their fibres. These textiles are especially used in sport garments next to the skin or in hot climates. In essence, the human body generates heat more quickly during exercise or vigorous activity. The body's cooling system attempts to dissipate this extra heat by producing perspiration. Perspiration should be removed readily from the skin surface or from the micro climate just above it, for maintaining comfortably cool and dry conditions.

Wicking is the spontaneous flow of the liquid in a porous substance, driven by capillary forces. Washburn[6] proposed the well-known Lucas–Washburn kinetics equation to describe the relationship between wicking length and wicking time. Crow and Randall[7], Kissa[8], Weiyuan *et al.* [9] investigated wetting and wicking behaviour of textiles. As capillary forces are caused by wetting, wicking is a result of spontaneous wetting in a capillary system. Wicking takes place only in wet fabrics and the contact angle decides the wicking behaviour.

According to Sailen[2], wool is highly moisture absorbent because its constituent keratin is very rich in amino acids which easily bind together the water molecules. Wool can absorb water vapour (30% of its own weight) without feeling wet[2].

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This paper reports the development and optimization of functional yarns based on wool fibres for different applications. In this study, wool is combined with moisture management materials to create intimate blends of different fibres. These new blended yarns with different percentages of wool and functional fibres were then used to produce knitted fabrics and the performance of these structures was evaluated. Two main evaluation methods (vertical wicking and horizontal wicking) for studying the liquid transfer behaviour through textile materials were used. Drying capability testing was carried out at two different conditions, namely standard (20±2ºC and 65% RH) and at 33ºC to simulate the body skin temperature. These two parameters play an important role on the performance of clothing for professional sport players. The influence of different fibres in each sample produced has also been evaluated.

2 Materials and Methods

2.1 Materials

Wool fibres (19µ) with Basolan treatment were combined in different proportions with moisture management fibres: Finecool (2.4 dtex) and Coolmax (2.4 dtex).

Yarns with 100% the same material, blends with 50% of wool and 50% of moisture management fibres, and blends with 75% of wool and 25% of moisture management fibres have been developed and produced. All the yarns produced have a linear density of 20 tex with 630 turns/m of twist.

Table 1 shows the dimensional properties of single jersey knitted fabrics, produced on a circular weft knitting machine (E28 gauge).

Table 1 – Dimensional properties of knitted fabrics produced

Fabric	Cover factor (K)	Aerial mass g/m^2	Density (wales × courses)/cm	Thickness mm
Wool	15.68	155.23	16 ×20	0.68
Polyester	16.86	168.73	14 × 22	0.67
Wool/Polyester (50:50)	16.28	147.67	14 × 20	0.64
Finecool	16.64	158.91	14 × 21	0.71
Wool/Finecool (50:50)	15.79	164.11	15 × 19	0.66
Wool/Finecool (75:25)	17.12	161.53	16 × 19	0.68
Coolmax	16.40	163.49	15 × 19	0.63
Wool/Coolmax (50:50)	16.18	154.68	14 × 20	0.61
Wool/Coolmax (75:25)	16.76	160.89	16 × 20	0.71

2.2 Methods

2.2.1 Vertical Wicking Testing

Vertical wicking testing was performed on the apparatus as shown in Fig. 1. Five specimens of 200×25mm size cut along wale-wise and course-wise directions were prepared. The specimens were suspended vertically with their bottom ends dipped in a reservoir of distilled water. In order to ensure that the bottom ends of the specimens can be immersed vertically with 30mm depth into the water, the bottom end of each specimen was clamped with a clip (Fig. 1). The wicking heights, measured after every 30 s till 5 min, were recorded as a direct evaluation of the fabric wicking ability.

2.2.2 Horizontal Wicking Testing

Figure 2 shows the apparatus used to evaluate the horizontal wicking rate under standard environmental conditions (20±2ºC and 65±2 % RH). In the horizontal

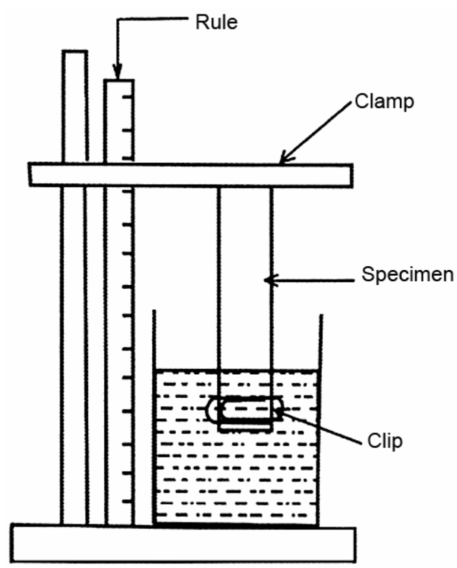

Fig. 1 – Vertical wicking apparatus

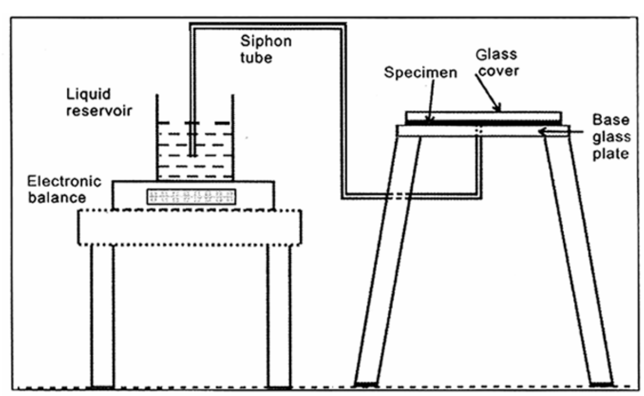

Fig. 2 – Horizontal wicking apparatus

wicking apparatus, a tiny water drop contact with the horizontally placed specimen (200mm×200mm) was provided, leading to the water absorption by wicking and wetting through the pores. The water was supplied continuously from a reservoir by siphoning. The reservoir was kept on an electronic balance, which enables to record the water mass absorbed by the fabric. Because the mass absorbed by the sample is related to the sample thickness, water absorption per unit of thickness is used to evaluate the horizontal wicking ability. The wicking was measured after every minute till 10 min.

2.2.3 Drying Rate Testing

Quick drying capability of the fabric was evaluated by its drying rate. The specimen of the size 200×200 mm^2 was put on the plate of the balance and the dry weight was recorded as w_f (g). The weight of water previously added in fabric was equal to 30% of the dry weight and then the wet weight was recorded as w_o (g). The change in weight of water [w_i (g)] at regular intervals was continuously recorded. The remained water ratio (RWR) was calculated using the following equation to express the change in water weight remained in the specimen over the time for drawing the evaporating curve from 100% to 0%:

$$\text{RWR}\ (\%) = \frac{(w_i - w_f)}{(w_0 - w_f)} \times 100\% \qquad \ldots (1)$$

In order to assess the quick drying capability of the fabric in different conditions, two testing conditions, namely standard condition (20±2ºC and 65±5 % RH) and at 33±2ºC temperature were chosen. For the first condition, the mass of water [w_i (g)] has been measured after every 5 min continuously for next 60 min. For the second condition, the mass of water [w_i (g)] has been recorded continuously after every 1 min till the next 5 min, and in the next 30 min after every 5 min.

3 Results and Discussion

3.1 Wicking Ability

3.1.1 Horizontal Wicking

Figure 3 shows the results obtained for horizontal wicking testing. Considering that during intense physical activity, when the body starts perspiration, quick moisture transportation is important; the results have been analyzed after the first minute. The performance ranking of fabrics (from the best to the worst) is shown below:

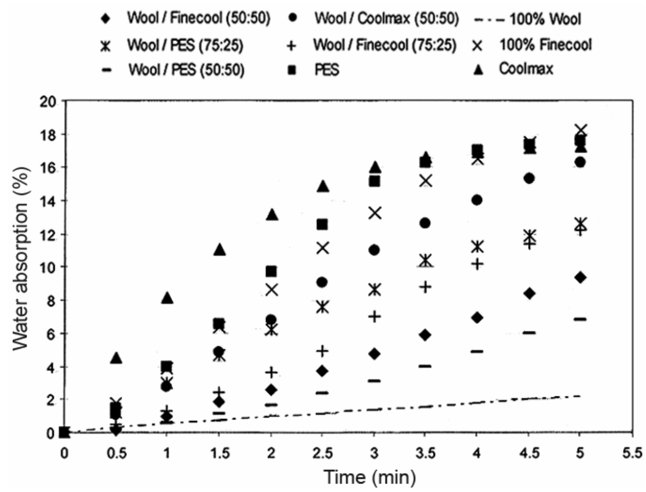

Fig. 3 – Horizontal wicking curve

Coolmax > Finecool > Polyester > Wool / Coolmax (75:25) > Wool / Coolmax (50:50) > Wool / Finecool (75:25) > Wool / Finecool (50:50) > Wool / Polyester (50:50) > Wool.

It can be seen that the fabric with 100% Coolmax fibres shows the best performance. Moreover, the fabrics with 25% and 50% of Coolmax show better performance than those with the same amount of Finecool. Fabric with 100% wool presents the poorest behaviour.

For fabrics produced with 100% of the same material, it is possible to easily identify the trends of horizontal wicking behaviour, as the diameter of the fibres in the yarn structure is constant. When different fibres are blended, their diameters vary according to the fibres density, leading to the different arrangements in the yarn and consequently different wicking channels.

3.1.2 Vertical Wicking

Figure 4 shows the results obtained for vertical wicking in the course-wise and wale-wise directions. Based on the findings at 1st min, performance ranking (from the best to the worst) is shown below:

Course-wise direction: Coolmax > Polyester > Wool / Finecool (75:25) > Wool / Coolmax (50:50) > Finecool > Wool / Coolmax (75:25) > Wool / Finecool (50:50) > Wool / Polyester (50:50) > Wool

Wale-wise direction: Coolmax > Polyester > Wool / Finecool (75:25) > Wool / Coolmax (50:50) > Finecool > Wool / Coolmax (75:25) > Wool / Polyester (50:50) > Wool / Finecool (50:50) > Wool

It is found that the 100% Coolmax fabric shows the best performance in both directions, and for all the other fabrics the results are very similar in both

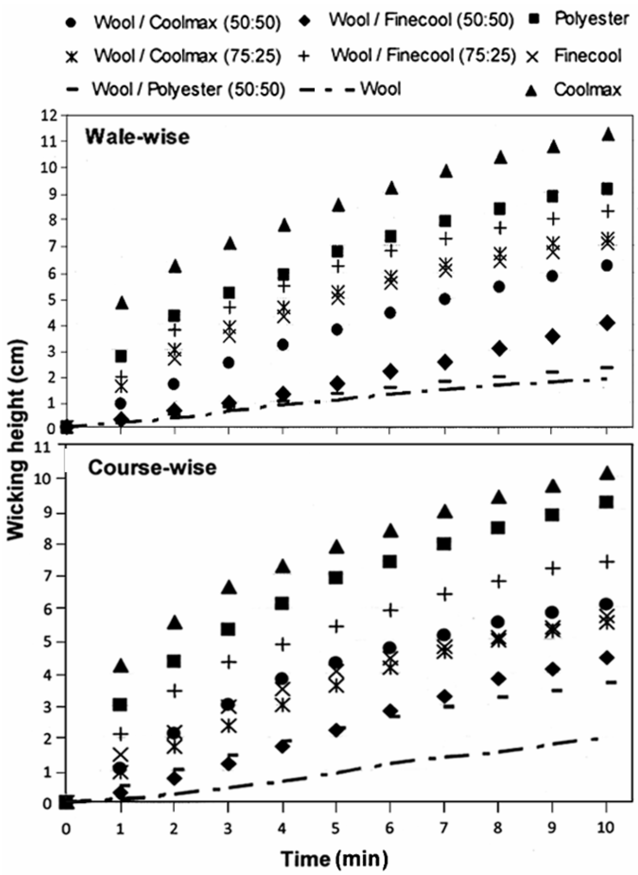

Fig. 4 – Vertical wicking curves

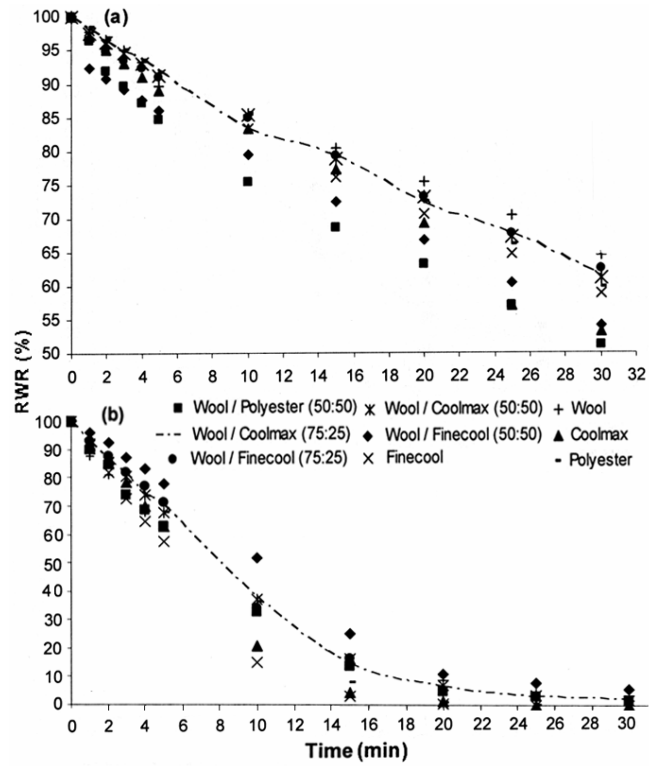

Fig. 5 – Drying rate (a) at standard conditions, and (b) at 33ºC temperature

course-wise and wale-wise directions. The fabric with 75% wool and 25% Finecool gives very good results, better than that of the fabric with 100% Finecool in both directions. 100% wool fabric shows the poorest results.

3.2 Drying Rate

Figure 5 shows the results obtained for drying rate both at standard conditions and at 33ºC temperature. Based on the results at 5 min, performance ranking (from the best to the worst) is shown below:

At 33ºC temperature: Finecool > Wool > Wool / Polyester (50:50) > Coolmax > Wool / Coolmax (50:50) > Polyester > Rest

Standard conditions: Wool / Polyester (50:50) > Wool / Finecool (50:50) > Coolmax > Wool > Wool / Finecool (75:25) > Finecool > Rest

It is observed that the fabric with 100% Finecool fibres shows the best performance under both the conditions. The fabric with 50% wool and 50% polyester shows better performance than that of the 100% polyester fabric.

Analyzing the behaviour in both conditions, one can observe that, as expected, for the same material and considering the same testing time, the RWR is lower for the skin conditions as the heat provided by the environment enables quicker evaporation. As a consequence, the slope of the RWR *vs* time curve is higher than that obtained under normal conditions. Moreover, the curve shows an inflection point at about 15 min, corresponding to a lower evaporation. In fact, the first part of the behaviour, represented by higher slope, corresponds to the moisture release from fabric and the second part of the curve, with a lower slope, corresponds to the moisture release from fibres.

3.3 Influence of Amount of Fibre

Figures 6-8 show the performance of different blends, depending on the different percentages of wool and functional fibres. It is observed that in horizontal wicking, the increase in amount of wool in the fabrics leads to a decrease in the absorption. However, the fabrics with 75% wool and 25% functional fibre show better performance than that of fabrics with 50% wool and 50% functional fibre. In vertical wicking, similar conclusions may be observed. However, in this case, fabrics with 75% wool show poor performance than those of fabrics with 50% wool. For horizontal wicking, Coolmax

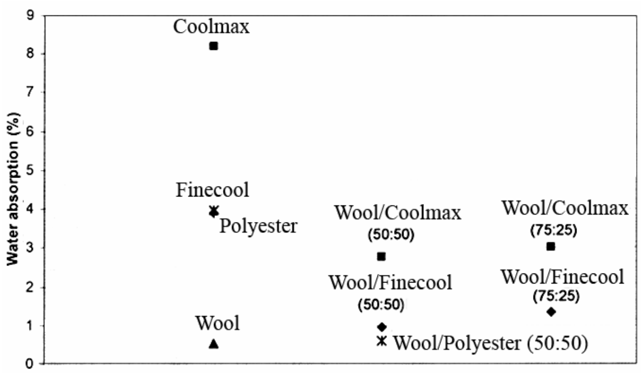

Fig. 6 – Influence of type of fibre at the end of 1st min in the horizontal wicking

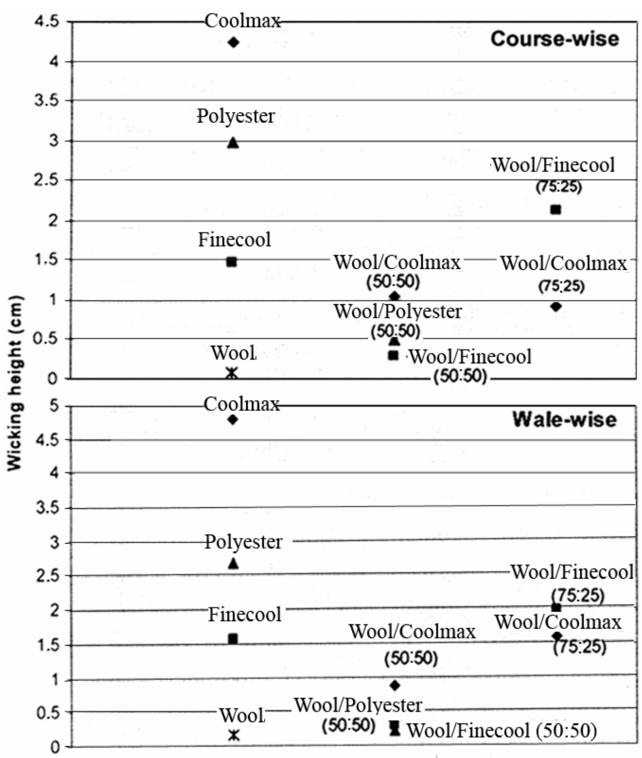

Fig. 7 – Influence of type of fibre at the end of 1st min in the vertical wicking

gives better performance for all proportions of functional fibre (100, 75 and 25%). In vertical wicking, the trend is similar but fabric with wool/Finecool (75:25) shows the best performance. However the performance is very similar in course-wise and wale-wise directions for all other proportions of different fibres.

In the drying rate performance, the variation in the amount of different fibres used in the blends leads to different behaviour for both the testing conditions. It is observed that the decrease in amount of Coolmax in

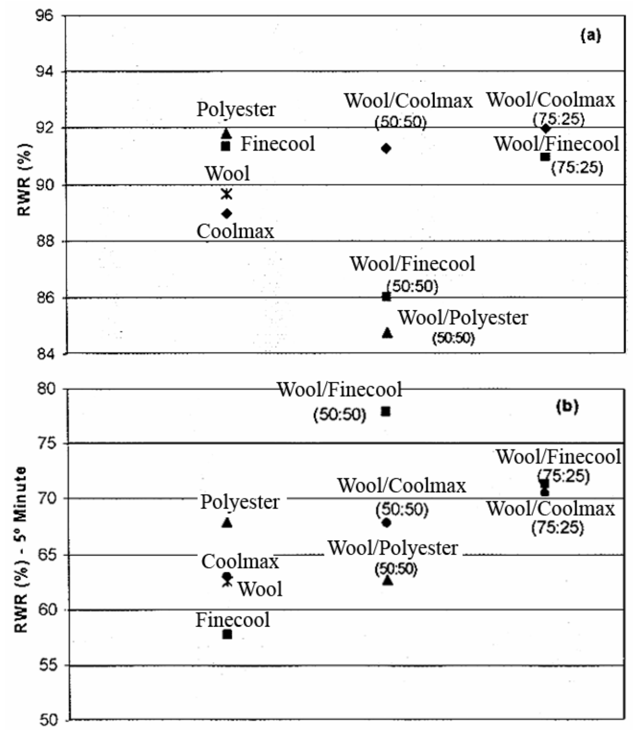

Fig. 8 – Influence of type of fibre at 5 min on the drying rate [(a) standard conditions, and (b) 33°C temperature]

the blends is directly related to the decrease in drying rate for both testing conditions. For Finecool, it is not possible to detect a clear trend. For standard conditions, fabric with 50% Finecool shows very good behaviour, however it gives worst performance for human body testing conditions.

4 Conclusions

Fabrics with Coolmax fibres show the best capillarity performance, i.e. they can transport quickly the humidity (perspiration) from the skin to the environment. Finecool fabrics show higher drying rate, i.e. high capacity to dry after wet. Wool fibre based fabrics show low water absorption performance, but a good drying rate. The increase in the percentage of wool fibre in the fabrics is directly related to the decrease in water absorption performance, however it does not lead to an increase in the drying rate.

The findings help in designing the most suitable combination of wool/functional fibres for end-uses, where moisture management is an important issue. The quantity of functional fibres can also be optimized to produce the economical products of the market demands.

Acknowledgement

The authors are thankful to the IAPMEI – Instituto de Apoio às Pequenas e Médias Empresas, for funding this project under the framework of PRIME Programme – I&DT Projects.

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