Indian Journal of Fibre & Textile Research
Vol. 32, December 2007, pp. 446-452

Effect of fabric softener on thermal comfort of cotton and polyester fabrics

M Parthiban[a] & M Ramesh Kumar[b]

Department of Fashion Technology, PSG College of Technology, Coimbatore 641 004, India

Received 12 April 2006; revised received and accepted 10 April 2007

The effect of fabric softener on thermal comfort properties, such as air permeability, thermal insulation value and wickability, of cotton and polyester fabrics after repeated laundering have been studied. It is observed that the fabric softener treatment with different levels significantly decreases the air permeability and wickability of cotton fabrics but does not affect the polyester fabrics properties. The softener treatment increases the thermal insulation value of both cotton and polyester fabrics to a similar degree. Statistical analysis also indicates that the results are significant for air permeability, thermal insulation value and wickability of the fabrics. The chemical finishing has a significant influence on the thermal comfort properties of cotton and polyester fabrics after repeated laundering cycles.

Keywords: Air permeability, Cotton, Polyester, Thermal insulation value, Wickability

IPC Code: Int. Cl.[8] D06B1/00

1 Introduction

Fabric softeners have been used for more than 50 years. Several studies have been conducted on the effects of softeners on fabric properties, such as the appearance properties (wrinkle recovery, pilling, and whiteness) and maintenance properties (dimensional stability and stain release). However, the studies on the effect of fabric softeners on comfort properties such as hand, static electricity and thermal comfort are scanty.

It has been observed that the wickability, air permeability and heat transfer influence the thermal comfort of a garment. It is very important for the textile to have the ability to absorb moisture vapour from the skin.[1] Whenever fibres absorb liquid water or moisture vapour, heat is released, and therefore, water absorbency of fabrics is an important factor that affects the wearer thermal comfort.[2] Air permeability is another factor related to the thermal comfort of a garment. In some products, such as sportswear and summer clothes, high air permeability is desirable. However, for some products, such as outerwear, tents, sleeping bags, blankets and protective textile products, low air permeability is required to keep the wearer comfortable.[3,4] Heat transfer is also one factor affecting thermal comfort. Heat transfer refers to the transfer of heat energy from a hotter environment to a cooler environment.[5] If the temperature of an environment is lower than the body, heat will be transferred from the body to the environmental surroundings and as a result, people would feel cool. In contrast, under hot conditions, heat will flow from the environment to the body to make people feel warm. In either direction, textiles can provide the resistance to heat flow as insulation between the two environments; thus more heat will be kept near the body and less heat will flow through the fabrics. The amount of trapped air that is contained within a textile structure determines the thermal insulation of a fabric. Regarding the relationship of fabric softeners and thermal comfort, some researchers have examined the effect of softeners on water absorbency.[6]

They found that softeners would decrease water absorbency. However, other factors that influence thermal comfort,[7,8] such as thermal insulation value and air permeability, have not been examined. Repetitive use of fabric softeners during the laundering process may leave residue of softener on the fabrics, which may create a barrier to airflow and wickability of the fabric. The present work was, therefore, undertaken to study the influence of fabric softeners on the thermal comfort in terms of wickability, thermal insulation and air permeability.

2 Materials and Methods

[a]To whom all the correspondence should be addressed.
E-mail: parthi_mtech@yahoo.com
[b]Present address: Department of Textile Technology, SSM College of Engineering, Komarapalayam 638 183.

2.1 Materials

Fabric samples having the following specifications were used:

Polyester – (i) 150 × 40 D, 121.2 g/m^2, 1.29 mm; and (ii) 80 × 40 D, 67.2 g/m^2, 1.21 mm.

Cotton – (i) 20s, 153.2 g/m^2, 0.26 mm; and (ii) 60s, 122.3 g/m^2, 0.41 mm.

Based on the ratings of fabric softener brands in consumer reports, the commonly used cationic softener Conc Soft P was procured commercially. The fabric samples thus obtained were tested for thermal comfort properties, namely thermal insulation value, air permeability and workability.

2.2 Test Methods

2.2.1 Laundering

The test fabrics were laundered according to AATCC test method 124-1996 — for appearance of fabrics after repeated home laundering (AATCC, 2001). A Maytag automatic washer (Model A806) was used for laundering the fabrics. The washing machine was set on regular wash, regular spin, warm wash, warm rinse, and normal water level conditions, in which the warm water temperature was 41°±3°C and 62±0.1g of detergent was used. Fabric specimens were added and washed for 12 min. After the rinse cycle, there was a final spin cycle for 5-6 min. Immediately after the final spin cycle, the washed load was placed in a tumble dryer with permanent press setting at the exhaust temperature of 66°±5°C.

2.2.2 Air Permeability

The air permeability test was conducted according to ASTM standard test method (ASTM 2000), using the Shirley air permeability tester. The test fabric specimens were preconditioned in a standard atmosphere of 21°±1°C temperature and 65±2% relative humidity for 24 h according to the ASTM standard practice for conditioning textiles for testing. After the two spring loaded hinged fasteners that hold the fabric clamp assembly were unlatched, the clamp assembly was opened. The test specimen was placed on the circular clamping assembly so that it lay flat and overhung at least one inch all around. A fabric clamping ring was placed over the specimen and circular plate was seated against the wooden part of the clamp assembly to hold the specimen to the plate smoothly without stretching. The fabric clamp assembly was raised up to the position where two circular plates were parallel to each other with the gasket and the fabric specimen held between them. The hinged fasteners were repositioned to hold the entire assembly together by the springs in the fasteners. The water pressure differential across the fabric specimen was 0.5 inch water. From the vertical manometer, the pressure drop in inches of water was read. The flow metering orifice and the corresponding conversion chart for converting pressure drop inches to air flow value determined the air permeability (cm^3/cm^2/min) value of the specimen.

2.2.3 Thermal Insulation Value

Thermal insulation value was assessed using SASMIRA thermal conductivity apparatus based on guarded hot plate method. The fabric sample was kept over the hot plate and time was noted for the temperature to drop down from 50° to 49°C. The clo (a measure of thermal insulation) was read form the graph of clo *vs*. time.

2.2.4 Wickability

The strip test was employed to measure the weft-wise wickability of fabrics. A sample (20 cm × 2.5 cm) was suspended vertically with its lower end immersed in a reservoir of distilled water for about 5 min, and the height attained by the water in the fabric above water level in the reservoir was noted. The wickability of the fabrics was calculated using the following formula:

Wickability = $(M \times H)$ /100

where M is the weight of water gained by the fabric strip as a percentage of the original weight of the fabric of a length equal to measured rise in height; and H, the height of water (mm) raised in fabric above the water level in the reservoir. The average height was calculated by measuring height at ten points marked across the fabric width.

2.3 Statistical Data Analysis

The statistical package program was used to analyze the data. The study for each thermal comfort property (thermal insulation value, air permeability, and wickability) was framed in 1-10 hypotheses which were examined by three-way analysis of variance (ANOVA) tests. The ANOVA results of each tested property are given in the Tables 1-3

Table 1—Three-way analysis of variance for thermal insulation value

Source	SS	DF	MS	F
Main effects	1073.38	8	134.17	229.37*
Fabric softener treatments	916.11	2	458.06	783.04*
Fabric types	94.52	1	94.52	48.51
Number of laundering cycles	22.28	2	11.14	19.04*
Fabric softener treatments × fabric types	373.52	2	186.76	39.63**
Fabric softener treatments × no. of laundering cycles	134.99	4	33.75	57.69*
Residual	21.06	36	0.59	-
Total	47233.34	45	-	-

*$p < 0.05$, and ** $p < 0.001$.
SS – Sum of squares, DF – Difference factor, MS – Mean squares and F – Test for significance.

Table 2—Three–way analysis of variance for air permeability

Source	SS	DF	MS	F
Main effects	117178.66	17	6892.86	1462.68*
Fabric softener treatments	1043.27	2	521.64	110.69*
Fabric types	112148.10	1	112148.10	23798.01*
Number of laundering cycles	3020.97	2	1510.49	320.53*
Fabric softener treatments × fabric types	373.52	2	186.76	39.63**
Fabric softener treatments × no. of laundering cycles	392.71	4	98.18	20.83*
Residual	339.30	72	4.71	-
Total	990326.50	90	-	-

*$p < 0.05$, and **$p < 0.001$.

respectively. The significant difference test was used to perform multiple comparisons between group means.

3 Results and Discussion

Each thermal comfort property is studied, considering 1-10 different hypotheses, as shown below:

(i) Hypothesis 1—Influence of fabric softener treatments on thermal insulation value

The thermal insulation value (TIV) increases with the increase in softener levels. It is found to be the lowest when no fabric softener is used. The softener treatment levels significantly increase the thermal insulation value of the fabrics (Fig. 1). These results support the research hypothesis H1, i.e. a significant difference is found between specimens with different fabric softener treatment levels (0, 1.5, 2.5 and 3.5%).

(ii) Hypothesis 2—Influence of fabric softener treatments and fabric types on thermal insulation value

A significant difference is observed between fabric softener treatments and fabric types on thermal insulation value. As the effect between fabric softener treatments and fabric types is significant, three-way ANOVA was conducted to examine the differences among three fabric softener treatment levels for each fabric type. The results show that there is a significant difference in the thermal insulation value with different fabric softener treatment levels for the cotton fabrics, but no significant difference is observed in polyester fabrics.

(iii) Hypothesis 3—Influence of fabric softener treatments and laundering cycles on thermal insulation value

There is no significant interaction between fabric softener treatments and number of laundering cycles. The results show that the influence of fabric softener treatments on thermal insulation value is similar in each selected laundering cycle. These results do not support the hypothesis H3, i.e. there is a significant interaction between fabric softener treatments and number of laundering cycles which influences the thermal insulation value of the specimen.

Table 3—Three–way analysis of variance for wickability

Source	SS	DF	MS	F
Main effects	894.21	17	52.60	27.00*
Fabric softener treatments	289.57	2	144.78	74.31*
Fabric types	94.52	1	94.52	48.51*
Number of laundering cycles	282.28	2	141.14	72.44*
Fabric softener treatments × fabric types	156.41	2	78.21	40.14**
Fabric softener treatments × number of laundering cycles	13.75	4	3.44	1.76*
Residual	140.29	72	1.95	-
Total	423698.42	90	-	-

*$p < 0.05$, and ** $p < 0.001$.

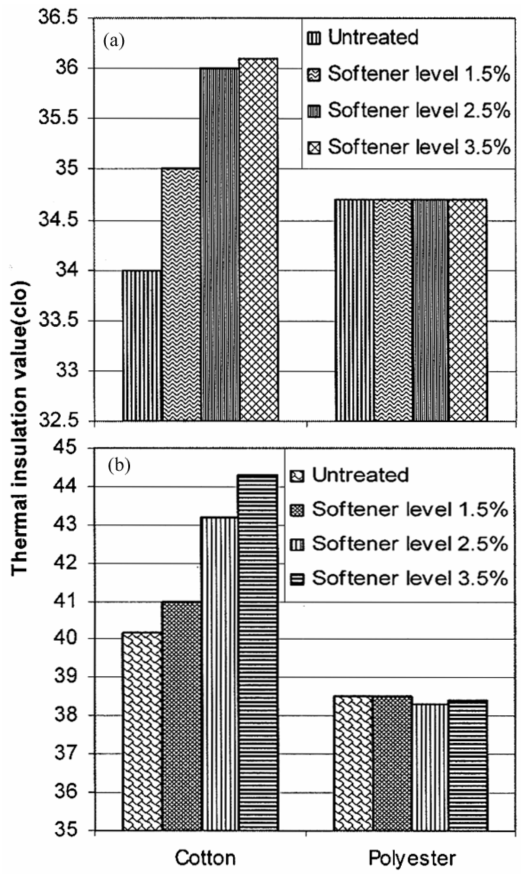

Fig. 1—Mean scores of thermal insulation values by fabric softener treatments for (a) coarser count and (b) finer count cotton and polyester fabrics

(iv) Hypothesis 4—Influence of interactions among fabric softener treatments, fabric types and laundering cycles on thermal insulation value

It is found that there is a significant interaction among fabric softener treatments, fabric types, and number of laundering cycles. For the polyester fabric, the results are similar to that of cotton fabric with and without using softener. No significant difference is found after 1, 3 and 5 laundering cycles, but after 7 laundering cycles, the thermal insulation value of polyester specimens significantly decreases. The thermal insulation value is significantly different after 5 laundering cycles instead of after 7 laundering cycles.

(v) Hypothesis 5—Influence of fabric softener treatments on air permeability

The mean scores of air permeability are found to be significantly different. The results show that there is a significant difference in the air permeability with different fabric softener treatment levels for the cotton fabric, but there is no significant difference for the polyester fabric (Fig. 2). Air permeability is found to be the highest when no softener is used.

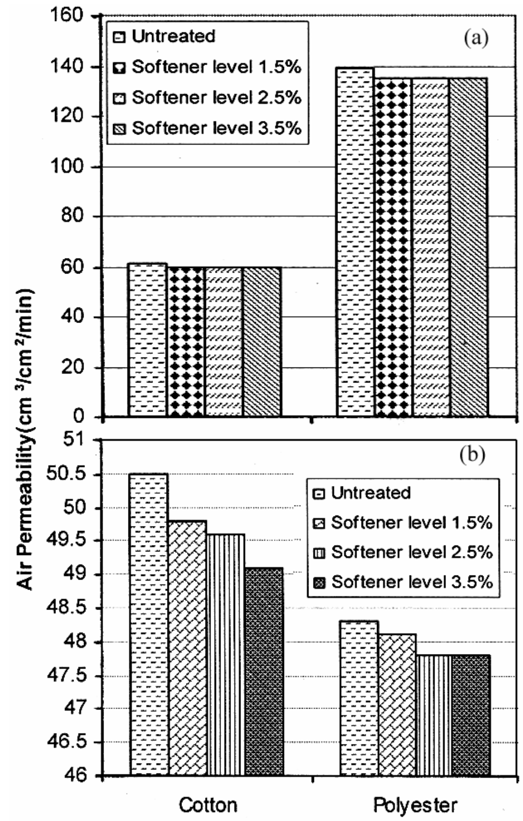

Fig. 2—Mean scores of air permeability by fabric softener treatments for (a) coarser count and (b) finer count cotton and polyester fabrics

(vi) Hypothesis 6—Influence of interactions between fabric softener treatments and fabric types on air permeability

There is a significant interaction between fabric softener treatments and fabric types. Only 3.5% softener treatment significantly decreases the air permeability of 100% cotton fabric. However, for the polyester fabric, the softener treatments show no significant influence on air permeability. These results show that the influence of fabric softener treatments on air permeability of the specimen is significantly different between the two fabrics.

(vii) Hypothesis 7—Influence of interactions between fabric softener treatments and laundering cycles on air permeability

It is observed that there is a significant interaction between fabric softener treatments and number of laundering cycles. The results show that the interaction between fabric softener treatment and number of laundering cycles has a significant influence on the air permeability of the specimen. The rate of decrease in air permeability with fabric softener treatments is different from the rate of decrease in air permeability with no softener treatment.

(viii) Hypothesis 8—Influence of interactions among fabric softener treatments, fabric types and laundering cycles on air permeability

The value of this hypothesis indicates that there is a significant interaction among fabric softener treatments, fabric types, and number of laundering cycles. For the cotton fabric treated with softener, the air permeability continuously reduces with the increase in laundering cycles. For the polyester fabrics, the air permeability reduces after 5 laundering cycles. However, unlike the cotton fabrics, the air permeability of polyester treated with fabric softener levels shows no further significant decrease after 5 laundering cycles.

(ix) Hypothesis 9—Influence of fabric softener treatments on wickability

The results are found to be significantly different among different fabric softener treatment levels. The softener treatment levels significantly decrease the wickability of the fabrics (Fig. 3).

(x) Hypothesis 10—Influence of fabric softener treatments, fabric types and laundering cycles on wickability

The result indicates that there is a significant effect of fabric softener treatments, fabric types, and number of laundering cycles on wickability. No significant difference is found after 1, 3 and 5 laundering cycles, but after 7 laundering cycles, the wickability of polyester specimens significantly increases. The wickability is significantly different after 5 laundering cycles instead of after 7 laundering cycles.

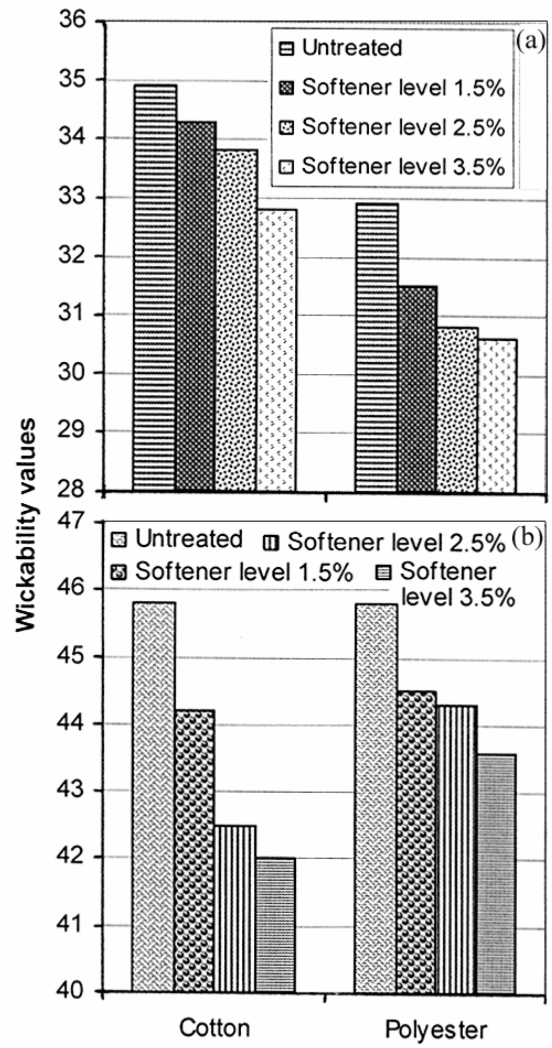

Fig. 3—Mean scores of wickability by fabric softener treatments for (a) coarser count and (b) finer count cotton and polyester fabrics

3.1 Effect of Fabric Softener on Thermal Insulation Value

All the softener treatments with different levels significantly increase the thermal insulation value of the fabrics. This might be related to the increase in fabric thickness. The changes in fabric thickness affect the resistance to heat of any particular cloth. As the fabric thickness increases, the resistance of the fabric to heat flow decreases. The influence of fabric softener treatment on thermal insulation values of cotton and polyester fabrics has been studied and it is found that the softener treatment levels show significantly different effects on the two fabrics. For cotton fabrics, softener treatments increase the thermal insulation value, while for polyester specimens treated by softener with different treatment levels it is similar to that of fabrics laundered with no softener. The possible reasons for this effect are fabric construction and the yarn structure in the two fabrics. Yarn structure plays an important role in influencing the thermal insulation value because a spun yarn or textured filament yarn entraps more air than a flat filament yarn and, therefore offers more resistance to heat transfer. The degree of twist also affects the thermal comfort. The higher twisted yarns are more compact, providing less air volume. Fabric construction also influences TIV. Knitted fabrics usually entrap more air than woven fabrics, although the tightness of weave or knit is a factor as well. Pile or napped constructions are often good to cold weather because the yarns or fibres perpendicular to the surface provide numerous spaces for dead air. This effect is maximized when such fabrics are worn with the napped or pile surface next to the body, or when they are covered with another layer. Otherwise, the protruding fibres in the nap structure may conduct heat away from the body.

The influence of softener treatments on the TIV of cotton and polyester fabrics after selected laundering cycles shows that the TIV of cotton fabrics significantly decreases after 7 laundering cycles, irrespective of the fabric softeners used. A possible reason for the decrease in the TIV of cotton fabrics after 7 laundering cycles might be related to the reduction in yarn twist due to the repeated laundering. When the cotton yarns are less twisted, they allow more heat to be absorbed into the fabrics and thus decreases the TIV of cotton yarns. Similar to cotton fabrics, the TIV of polyester fabrics treated with or without softener also significantly decreases after 7 laundering cycles. After 7 laundering cycles, the TIV of polyester fabrics treated with softener significantly decreases. A possible reason for the different decrease rates might be related to the increase in porosity of polyester fabrics.

3.2 Effect of Fabric Softener on Air Permeability

The softener treatment significantly decreases the air permeability of cotton fabrics but does not affect air permeability in case of polyester fabrics. It is found that the ability of a fabric to allow air to go through it freely is mainly dependent on the porosity of the fabric. When the degree of porosity is decreased, the fabric would become less permeable because little air is allowed to flow through the fabric. Another possible reason is the difference in the moisture-absorption property between the two fabrics. Cotton fibres are hydrophilic, and hence absorb a greater amount of softener. The absorbed softener within fibres could block the air space between fibres or yarns, resulting in decrease in air permeability. Another possible reason might be related to the fibre wetting effect of cotton fabrics. It is found that at a low differential pressure, hydrophilic fibres such as cotton would easily swell after absorption of water and the change in fabric porosity and thickness result in decrease in air permeability.

Polyester fibres are hydrophobic. The low moisture regain could not allow a great amount of softener buildup and swelling occurs which reduces the air permeability of polyester fabric. The softener is usually kept on the fabric surface. Fewer residues would be built up on the fabric and no swelling would occur. This might be the reason why the softener does not significantly affect on the air permeability of polyester specimens.

The influence of softener treatments on the air permeability of the fabrics has been analyzed after selected laundering cycles; the softener with different levels reduces the air permeability of fabrics after 5 laundering cycles. After 7 laundering cycles, the softener continuously decreases the air permeability of fabrics. This property may be due to the buildup rate of softener residues on the fabric. The influence of softener treatments on the air permeability of the fabrics has also been analyzed between cotton and polyester fabrics after selected laundering cycles. The results show that for the cotton fabric, no matter whether fabric softener is used, the air permeability continuously reduces with the increase in laundering cycles. However, the air permeability of cotton fabrics treated with the softener decreases more than that of the fabric used without softener. A possible reason for the reduction in the air permeability of fabrics even though no softener is used might be related to the buildup of detergent residues on the fabric, which also could decrease the air permeability of fabrics. The air permeability of polyester fabrics treated with softener significantly decreases after 5 laundering cycles but there is no further decrease with the further increase in laundering cycles. A possible reason for this might be related to the saturation of buildup. The polyester fabric is negatively charged, and the fabric softeners are positively charged, all the cationic softeners would be picked up by the polyester fabric and be kept on the fabric during the laundering process. After the 5th laundering cycle, it is possible that the bond of the polyester fabric and fabric softeners attains a relatively saturated stage, and thus, when laundering cycles continuously increases, the buildup of softener residues on the fabric would not significantly increase.

3.3 Effect of Fabric Softener on Wickability

There is a significant decrease in wickability of specimens with the fabric softener treatments for cotton fabrics. However, the wickability of polyester fabrics treated with softener is found to be similar to that of fabrics laundered without fabric softener. The reasons might be related to the different moisture-absorption characteristics and the yarn structure of the two fabrics. Fibre content plays an important role in influencing the wickability because water vapour is absorbed by fibres, transported through fibres, and then desorbed to the environment. In this process, the inherent absorbency of the fibres or their affinity for water determines the process of wickability. Cotton fibre is hydrophilic (water-loving), which can absorb significant amount of moisture. As more softeners were absorbed into the cotton fibre, the wicking capacity of cotton fabric would decrease due to the reduced capillary spaces in the fabric. This led to the decrease in wickability of the fabric. However, polyester fibre is hydrophobic (water-avoiding), which can absorb very little amount of water. Because less amount of the softener would be absorbed into the polyester fabrics, it does not influence the wickability of polyester fabric. A possible reason for this might be related to the protruding fibre ends of cotton yarns on the surface. Cotton fibres are staple length fibres (the length ranges from 0.75 to 18 inch) and the fibre ends of staple fibres usually come out from the yarn strand, especially after repeated wear and laundering. The short fibre ends of cotton fibres create a fuzzy surface and make the softener more easily to adhere on the fabric. As more softener is retained on the surface of the cotton fabric, they would reduce the wicking capacity of cotton fabric. Polyester fabric is made with filaments (the length could be infinite). The round and smooth structure of filament fibres could prevent a large amount of softener from remaining on the fabric, and therefore the wickability of polyester fabric treated with the softener or without softener was similar. The influence of softener treatments on the wickability of the fabrics is analyzed between cotton and polyester fabrics after selected laundering cycles. The results show that the wickability of cotton fabrics significantly increases after 7 laundering cycles, irrespective of type of fabric softeners.

The wickability of polyester fabrics treated with or without softener or the softener also significantly increases after 7 laundering cycles. However, the wickability of polyester fabric treated with the softener increases faster than the fabric with no softener. This might be due to the different degree of increase in yarn slippage. The lubrication of fabric softener in yarns could cause yarn slippage, which increases the porosity of polyester fabric. The transport of vaporous and liquid water through polyester fabric is mainly determined by the porosity of the fabric due to the low moisture regain.

4 Conclusions

The fabric softener treatment with different levels significantly decreases the air permeability and wickability of cotton fabrics but has no effect on polyester fabrics. The softener treatment increases the thermal insulation value of both cotton and polyester fabrics to a similar degree. Statistical analysis also indicates that the results are significant among the values on air permeability, thermal insulation value and wickability of the fabrics. The significant findings of this study are based on the statistical results. Responses from consumers may not be the same as the statistical results. For example, an influence proved to be statistically significant may not be identified by consumers. On the other hand, consumers may distinguish differences that are not statistically significant. Wear studies are needed in the future to understand consumer's responses regarding the effects of fabric softeners on textiles. The influence of softener treatments on wickability, air permeability, and thermal insulation of the fabrics may help manufacturers to provide better care instruction for their textile products. This would certainly help to construct a more relevant appraisal of the fabric softener related contributions to thermal comfort performance

References

1 Taylor M A, *Technology of Textile Properties* (Forbes Publications, London), 1991.
2 Tortora P G & Collier B J, *Understanding Textiles* (Prentice Hall Inc., New Jersy), 1997.
3 Collier B J & Epps H H, *Textile Testing and Analysis* (Prentice Hall Inc., New Jersy), 1999.
4 Kadolph S J, *Quality Assurance for Textiles and Apparel* (Fairchild Publications, New York), 1998.
5 Willams J A, How to choose cationics for fabric softeners, *Soap/Cosmetics/ Chemical Specialists*, 59 (8) (1982) 28-32.
6 Egan R.R, Cationic surface-active agents as fabric softeners, *Oil Chemists' Soc*, 55 (1) (1978) 118-121.
7 Slater K, *Human Comfort* (Charles C Thomas Publisher, Springfield IL), 1985.
8 Branson D H & Sweeney M, Sensorial comfort. Part I: Psychophysical method for assessing moisture sensation in clothing, *Text Res J*, 60 (7) (1990) 371-377.
9 Gordon S, *Australian Cotton Grower*, 1 (2002) 28.
10 Tyagi G K & Dhirendra Sharma, *Thermal comfort characteristics of polyester-cotton MVS yarn fabrics*, *Indian J Fibre Text Res*, 30 (2005) 363.