Thermo-physiological Comfort Properties of Polyester and Polyester/Acrylic blended Synthetic Fabrics treated with Herbal Finishes

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ABSTRACT

Thermo-physiological comfort in clothing mainly lies in moisture management, which often refers to the transport of both moisture vapor and liquid away from the body. Moisture management of fabrics is chiefly influenced by the thermal properties of those fabrics. In spite of the convincing properties that synthetic fabrics have, they are not much preferred because of their hydrophobic nature which provides less comfort to the wearer compared to the natural fabrics like cotton, wool, and silk. Previous studies report that the herbal finishes, which are eco-friendly in nature, improve the anti-microbial and other medicinal properties but very little or no work has been carried out on the comfort aspect of these fabrics.

This work reports a study of the influence of two eco-friendly herbal finishes, Neem and Bermuda grass, on the thermo-physiological comfort properties of synthetic fabrics used in clothing. The herbal finishes were applied on to 100% Polyester and 50/50 Polyester/Acrylic blended fabrics. Prior to the application of finishes, the fabrics were given a pre-treatment to achieve a better penetration and durability of the finishes. The finished fabrics were tested for the thermo-physiological comfort properties of Wicking, Water vapor permeability, and Thermal conductivity and the results were analyzed. It was revealed that both the Neem and Bermuda grass natural finishes considerably improved the moisture related properties and moderately reduced the thermal conductivity characteristics of the above synthetic fabrics. Durability to washing was also tested and discussed.

Keywords: Clothing comfort**,** Herbal finishes, Synthetic fabrics, Thermal conductivity, Thermo-physiological comfort, Water vapor permeability

INTRODUCTION

The outcome of any activity mainly depends upon the ease or comfort with which it was performed. If the comfort level is high, the effectiveness of the activity will be high, thus the result also will be the best. Since clothing is in constant contact with the human, the success of any activity in a day is mainly affected by the comfort offered by the fabric material worn by them.

Thermo-physiological comfort includes moisture and thermal related properties. An important feature of any fabric is how it transports the sweat water out of the body surface, so as to make the wearer feel comfortable [1]. For a person engaged in normal routine indoor activity, the metabolic heat generated is readily dissipated through the clothing as sweat. During sporting activity the metabolic heat increases six times and perspiration 14 times [2].

Li (2001) studied thermo-physiological comfort of clothing and defined it as the garment's ability to keep the wearer dry and to regulate body temperature during a change in the environmental temperature or humidity, and during physical activity, contributing to the thermal equilibrium of the body [3].

Of late, this aspect of clothing is being focused as many researchers are finding ways and means for providing maximum comfort to the wearer. R. K. Varshney et al. [4] reported that the linear densities and profiles of polyester fibers have an effect on the physiological properties of their fabrics. It was revealed in a previous study that bamboo fiber presence in the fabrics has an effect on the thermal comfort properties of knitted fabrics [5]. It was also discussed that some hydrophilic treatments on fabrics improve the comfort properties. Suthasinee Ploymalee et al. [6] reported that, coating of

Polyethylene glycolated bisphenol A (PEGBPA), a hydrophilic compound, imparts a durable hydrophilic property on to polyester fabric.

Nature has rendered many excellent things for the well-being of the human being for many years. In recent times, researchers have found that some herbs are considered to be the best alternative to certain diseases which may in some cases lead to chronic diseases and disorders.

M. Joshi et al. observed that neem treated fabrics inhibited the growth of Gram-positive bacteria (*Bacillus subtilis*) by more than 90% as compared to the control sample, thus improving the antimicrobial property of synthetic fabrics [7]. The neem tree (*Azadirachta Indica*) originates from the Indian subcontinent and now grows in the dry regions of more than 50 tropical countries around the world.

Likewise, Bermuda grass (*Cynodon dactylon)* is a grass native to North Africa, Asia, Australia, and southern Europe. Its medicinal property and the tradition of indigenous system of therapy, specifically the Ayurveda, are always accounted for as the traditional value of India. In one research study [8], it was revealed the ethanolic extract of one variety of Bermuda grass was found to have most potent antioxidant capacity.

As discussed, considerable research has already been carried out on the antimicrobial and other medicinal properties of textile fabrics treated with neem and Bermuda grass, but no reports on their comfort properties have been made. Some herbs are considered to have a natural cooling effect, and this helps in cooling purposes at certain specific circumstances. In this context, neem is used as a cooling agent for persons affected by chicken pox. It also helps in suppressing extra heat generated in the body, helping to maintain normal condition in hyperthermia. Similarly, very little information is available on bermuda grass and its products in research papers, and awareness about its excellent properties is limited and needs to be enlightened.

In spite of the convincing properties that the synthetic fabrics have, they are not much preferred because these fabrics are hydrophobic in nature and provide less comfort for the wearer. Hence an attempt was in this work, to study the influence of neem and bermuda grass herbal finishes on the thermo-physiological comfort aspects of 100% Polyester and 50/50 Polyester/Acrylic synthetic fabrics. Important reasons for selecting these herbs are that, they are eco-friendly and available abundantly in nature. Both Neem and Bermuda grass herbal finishes were applied on to the fabrics and the thermo physiological comfort properties of wicking (both ways), water vapor permeability, thermal conductivity, and durability to washing were studied and the results discussed.

EXPERIMENTAL

Materials

Two types of woven fabrics: 100% polyester and 50/50 polyester/acrylic were selected for study. These fabrics were chosen since they are commercially preferred synthetic fabrics for shirting.

Neem and Bermuda grass finishes were chosen for their application on to the fabrics. These two natural finishes were chosen because; they are eco-friendly and have merits in imparting moisture related properties. The extracts of these two herbs were prepared as per the regular procedure adopted for herbal extract preparation.

Methodology

Pretreatments to the Fabrics

All fabrics were procured as finished ones that can be directly used for garments. But, in order to remove the dust particles and other impurities present in them, they were given a normal washing treatment with a detergent in a washing machine and dried. The hydrophobic nature of synthetic fabrics naturally does not allow the maximum penetration of herbal finishes. Hence, a pre-treatment with Hy-soft silicon was accomplished so as to enhance the hygroscopic property of the synthetic fabrics which in turn will augment the herbal finish penetration and its durability. Keeping a set of fabrics as untreated for control, the remaining fabrics were given a pretreatment by using the following recipe:

Hy-soft silicon:	20 gpl
Acidic acid:	1gpl
Time:	25min
pH:	4.5
Temp:	80^0C

Then the fabrics were dried at 80^0C for five minutes and cured by placing in a curing chamber at 150^0C for three minutes.

Preparation of Extracts from the Herbs

The extracts are prepared using a Soxhlet apparatus. The extract preparation process included three steps namely, drying, granulating, and extraction. The above herbs were dried under shadow for about two weeks. The dried herbs were crushed to small pieces.

These small pieces of herbs were treated and extracted with methanol for 12 hours in a Soxhlet apparatus to get the extract.

Application of Herbal Finishes

All pretreated fabrics were then treated with the herbal extracts for fixing herbal finish over the fabrics. The regular pad, dry, and cure method was adopted. Extracts of both the Neem and Bermuda grass were applied over the fabrics as per the recipe and the procedure explained below.

The finishing bath was prepared using 1:15 ML ratio. Then 3% of the herbal extract is added. The well wetted, squeezed fabric was put into the bath as prepared above and kept for one hour at room temperature at 6-7 pH level followed by roll squeezing to get a wet pick up of 80%. Then the fabric was rinsed, dried at 80^0C for five minutes, and cured at 100^0C for three minutes. The fabrics were treated separately in the finishing bath.

Testing the Fabrics

The constructional parameters of both the types of fabric were determined by doing the relevant tests. Ends per inch and picks per inch were measured using a counting glass according to ASTM D3775-03 standard method.

TABLE I. Constructional parameters of synthetic fabrics.

Fabric type	EPI	PPI	Warp count (Ne)	Weft count (Ne)	GSM
100% Polyester	62	56	40^S	40^S	110
50/50 Polyester/Acrylic	56	53	40^S	40^S	114

Warp, weft yarn count, and fabric GSM were determined according to ASTM D1059 standard using electronic weighing scales. The test results are depicted in *Table I.*

The thermo-physiological comfort related properties such as wicking (both ways), water vapor permeability and thermal conductivity were measured using the relevant instruments, procedures and as per the ASTM standard test methods. The vertical wicking test was conducted using a vertical wicking tester according to DIN 53924 method. A strip of fabric (200mm X 25mm) was suspended vertically with its lower end (30mm) immersed in a reservoir of distilled water, to which 1% reactive dye (Prussian blue) was added for tracking the movement of water and at a regular time interval, the height reached by water in the fabric was measured with respect to the clamped scale by capturing images at regular interval. The test results are tabulated in *Table II.*

TABLE II. Vertical wicking height in cm.

Fabric type	Wicking direction	Control fabric			Neem finished fabric			Bermuda grass finished fabric		
		1 min	5 min	10 min	1 min	5 min	10 min	1 min	5 min	10 min
100% Polyester	Warp way	0.3	0.5	0.7	1.5	2.3	2.9	1.5	2.0	2.2
	Weft way	0.3	0.5	0.6	1.2	2.4	3.0	1.1	2.2	2.9
50/50 Polyester/ Acrylic	Warp way	0.2	0.3	0.4	1.4	1.6	1.7	1.8	2.4	2.8
	Weft way	0.2	0.3	0.4	1.1	1.3	1.4	1.4	2.0	2.3

The PERMETEST instrument was used to measure the water vapor permeability and thermal conductivity, working on simulated skin principle as recommended in ISO 11092. The concerned test results are depicted in *Table III.*

TABLE III. Other thermo-physiological properties of control and finished fabrics.

SNo.	Property	Type of fabric	Control fabric	Neem finished fabric	Bermuda-grass finished fabric
1	Water vapor permeability ($g/m^2/day$)	100% Polyester	2986.3	3051.01	3158.21
		50/50 Polyester/ Acrylic	3034.34	3134.18	3226.58
2	Thermal conductivity (Wm^1K^{-1})	100% Polyester	0.0321	0.0302	0.0278
		50/50 Polyester/ Acrylic	0.0257	0.0253	0.0198

RESULTS AND DISCUSSION

Wicking Behavior

The results of wicking behavior of 100% polyester fabric are given in *Table II*. From the results, it is evident that both herbal finishes improve considerably the wicking behavior of 100% polyester fabric both in the warp and weft.

The improvement is seen to the tune of three times (314%) with Neem finish and two times (214%) with

Bermuda grass finishes in the warp. In the case of weft way wicking, it can be observed that the improvement in wicking is four times (400%) with Neem finish and 3.8 times (383%) with Bermuda grass finish. The neem finish exhibits a better warp way wicking comparing to the Bermuda grass finish in both the cases.

The results of wicking behavior of polyester/acrylic blended fabric are given in *Table II*. It is evident from *Table II*, that both the herbal finishes improve considerably the wicking behavior of polyester/acrylic blended fabric both in warp and weft ways.

The improvement is about 3.25 times (325%) with Neem finish and 6 times (600%) with Bermuda grass finish in warp way. In the case of weft wicking, it is noted that the improvement in wicking is 2.5 times (250%) with Neem finish and 4.75 times (475%) with

Bermuda grass finish. It is noted that the Bermuda grass finish records a higher improvement in wicking property when compared with Neem finish in both the warp and weft directions.

The actual reason for this conflicting improvement in wicking with Neem and Bermuda grass finishes is not yet clearly known, since there is no evidence of literature or previous studies to prove this phenomenon. But seeing the actual test results and the fiber composition in both the fabrics, it may be concluded that the 100% polyester fabric is having more affinity to water absorption (wicking) with Neem finish, whereas, the 50% contribution by the acrylic fiber in the polyester/acrylic blended fabrics, leads to the higher affinity for wicking with Bermuda grass finish.

Thus, this finding proves that these herbal finishes on synthetic fabrics help in enhancing the absorbency of water through wicking, thus providing better comfort to the wearer.

Water Vapor Permeability

From *Table III*, it is noted that both the herbal finishes enhance the water vapor permeability behavior of 100% polyester fabric. The improvement is 64.66 g/m^2/day and 171.86 g/m^2/day with Neem and Bermuda grass finishes, accounting for 2.17% and 5.75% increase in water vapor permeability respectively. The Bermuda grass finish exhibits a better water vapor permeability compared to the neem finish.

Referring to *Table III*, it is noted that both the herbal finishes enhance the water vapor permeability behavior of polyester/acrylic blended fabric. The improvement is 99.79 g/m^2/day and 192.19 g/m^2/day with neem and Bermuda grass finishes, accounting for 3.29% and 6.33% increase in water vapor permeability respectively. Here also the Bermuda grass finish exhibits a better water vapor permeability comparing to the neem finish.

As a whole, the water vapor permeability properties of both the synthetic fabrics improve considerably, thus providing better comfort to the wearer. The actual reason for this phenomenon of improvement in water vapor permeability is not yet clearly identified, since there is no evidence of literature or previous studies to prove this finding. But this may be attributed to the reasons discussed in the introduction, as these herbs provide a cool environment, cool home, and are also used as a coolant for certain heat-induced diseases. But, a notable feature observed here is that with both the finishes, the 50/50 polyester/acrylic blended fabric showed an improvement compared to the 100% polyester fabric. Wider thread spacing in the former fabric may be one of the reasons for higher water vapor permeability when compared with 100% polyester fabric where the thread spacing is less due to the higher EPI and PPI.

Thermal Conductivity

Thermal conductivity results of both the fabrics are given in *Table III*.

It is evident from the results that, unlike the other moisture properties, the thermal conductivity of 100% polyester fabrics show a decrease with the herbal finishes. This decrease is very small as 5.92% (0.0019 $Wm^{-1}k^{-1}$) and 13.40% (0.0043 $Wm^{-1}k^{-1}$) with Neem and Bermuda grass finishes respectively.

Similar to polyester fabrics, it can be seen in *Table III*, that the thermal conductivity of the polyester/acrylic blended fabric shows a decrease with the herbal finishes. The Neem finish exhibits a very minute decrease of 1.55% (0.0004 $Wm^{-1}k^{-1}$) and the Bermuda grass finish shows a decrease of 23.73% (0.0061 $Wm^{-1}k^{-1}$). As a whole, the Neem has a very low decrease whereas the Bermuda grass has a moderate decrease in thermal conductivity with both fabrics.

In spite of the improvement in moisture properties, the thermal conductivity results show a decreasing trend in both the finishes, which indicates that these herbal finishes act as poor conductors of heat. Moreover, the air space between the threads in the fabric gives way for the presence of still air which is a poor conductor of heat, thus obstructing the heat transfer. Thus, in the P/A blended fabric, the air space is greater because of the wider spacing of threads (lower EPI & PPI), causing higher still air presence, ultimately lowering the thermal conductivity when compared with the 100% polyester fabric, where the thread spacing is less (higher EPI & PPI), giving lesser space for still air.

Finish Durability

The herbal finish durability was checked by testing the finished fabrics after 5 and 20 washes for their warp way wicking property. The washing was done using a standard detergent with 3% of its own weight at 40^0C in a washing machine as per the method ISO: 6330 – 1984E. The results are tabulated in *Table IV*.

TABLE IV. Finish durability in terms of % reduction in warp way wicking of fabrics.

Fabric type	% Reduction in warp way wicking of fabrics			
	After 5 washes		After 20 washes	
	Neem	Bermuda Grass	Neem	Bermuda Grass
100% Polyester	83.2	85.4	55.3	53.1
Polyester/Acrylic blend	85.1	88.3	58.5	55.0

It is evident from *Table IV* that the durability of both the finishes was lying in the range from 53% to 88.3%, after 5 and 20 washes. After 5 washes, Bermuda grass exhibits a very little higher durability than Neem to the tune of 2.2% and 3.2% for 100% polyester and polyester/acrylic blended fabrics respectively. Whereas after 20 washes, Neem shows a very little higher durability than Bermuda grass to the tune of 2.2% and 3.5% for 100% polyester and polyester/acrylic blended fabrics respectively. With reference to the types of fabric, the polyester/acrylic blended fabric had a better fastness comparing to the 100% polyester fabric. In general, both the Neem and Bermuda grass finishes show a good fastness to washing.

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CONCLUSION

- The moisture properties of wicking and water vapor permeability were improved using Neem and Bermuda grass finishes, thus providing a better comfort to the wearer
- The thermal conductivity showed a little decreasing trend with the herbal finishes
- The wicking (both ways) property of 100% polyester fabric with Neem was higher compared to the Bermuda grass finish, whereas it was opposite with the polyester/ acrylic blended fabric, and the Bermuda grass gave higher wicking than the Neem finish
- The water vapor permeability of both the fabrics improved considerably with the herbal finishes and this increase was higher with Bermuda grass comparing to the Neem finish in both the fabrics
- The decrease in thermal conductivity was very much less with the Neem comparing to the Bermuda grass finish in both the fabrics
- Both the Neem and Bermuda grass finishes showed a good fastness to washing
- As a whole, the thermo physiological comfort properties of 100% polyester and 50/50 polyester/acrylic blended synthetic fabrics were improved considerably in moisture-related properties and had very little decrease in thermal conductivity

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