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Optimization of thermo - physiological properties of structurally modified wool/polyester blended fabrics using desirability function

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The thermo-physiological properties of handloom fabrics produced with or without modified wool/polyester yarns in the weft has been studied. Yarn samples at different blend compositions are prepared according to mixture design at a different percentage of fibres using design expert software. The effect of percentage of different fibres, namely polyester, wool and PVA, on different thermo-physiological properties along with fabric properties obtained for different fibres after the dissolution of PVA component at yarn stage or fabric stage have also been studied. This paper also reports the potential of different fibres optimization to achieve maximum desirability for different thermo-physiological properties of treated (at yarn stage and fabric stage) and untreated fabrics with the help of desirability function. Treated fabrics at both stages show better thermo-physiological comfort properties as compared to untreated fabrics. In general, after dissolution of the PVA component both at the yarn stage or at the fabric stage, the treated fabric gives a higher value of thermal resistance, compressibility, drying capacity and water vapour permeability, while a lower value of air permeability and bending rigidity in comparison with untreated fabrics. Results of optimization for treated (at yarn stage and fabric stage) fabrics show higher overall desirability that can be achieved by using less percentage of wool fibres in case of treated fabrics (either at yarn stage or fabric stage).

Keywords: Blend composition, Desirability function, Handloom fabrics, Thermal resistance, Wool/polyester fabrics

1 Introduction

Thermo-physiological wear comfort, that depends on the heat and moisture transport properties of clothing and the way that clothing helps to maintain the heat balance of the body, is one of the basic and necessary properties of the fabric during various activities. Both the structures of yarn and fabric play vital role in deciding the comfort characteristics of any fabric. Thus, many researchers, by considering basic information of heat and moisture, try to improve the comfort properties by changing the structure of yarn and fabric. Structural modification can be done by chemical, mechanical, or combination of the both methods. The chemical method, i.e. dissolving one component, attracted the attention of many researchers for improving the comfort properties of fabrics. Nature, composition and arrangement of constituent fibres can influence the structure, properties and performance of yarn, which may ultimately influence fabric comfort properties[1–5]. Suitable structural modification by chemical treatment of both yarn and fabric can be helpful in entrapping air and creating static air pockets, which may resist transmission of heat through the garment and hence provide warmth.

Constituent yarn geometry plays a significant role in transport and related properties of a fabric, such as air permeability, water transmission rate, thermal resistance and liquid water transmission properties as suggested by Yoon and Buckey[6], Morris [7] and Ukponmwan[8] reported that thermal properties of textiles may be affected mainly by the type of fibre substance, thickness of fabric, enclosed still air and bulk density of fabric. Many researchers found that pore created by structural modification has a significant influence on physical, moisture and thermal behaviour of the fabrics[1-5].

A blending of natural with synthetic fibres give clothing and apparels the highest comfort, softness, strength, good look and functionality. Wool fibres are coarse and can lead to pricking and even irritation to the skin. Despite being considered as a premium fibre for the apparel sector, 100% woollen apparel is neither comfortable nor economical. Such fabrics may offer some good technical attributes but likely to lack dimensional stability. It is a critical problem in fibre blending technology to choose the appropriate type of

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fibres and blend ratios to obtain a final product. Mixture experiments are a particular class of response surface experiments in which the product under investigation is made up of several components or ingredient[9]. So, this design is suitable in situations, where the response is a function of the proportions of the different ingredients in the mixture[10].

In the present century, the clothing markets have become highly competitive due to high demand and fashion. Textile and clothing industries are searching for competitive advantage by understanding and meeting consumer needs and desires, to survive in the quickly changing, highly competitive clothing market. Many researchers developed different statistical techniques to satisfy the need of the industries, like response surface methodology and various optimization algorithms, e.g. desirability function-based approach[11,12], multiple regression and linear programming based approaches[13] and utility function-based approach[14]. Among various approaches for multi-response optimization, the desirability function-based has gained the maximum popularity in solving the multi-response optimization problems. Ghosh *et al.*[15] optimized different comfort properties and safety properties using desirability function to yield overall desirability varying from zero to one. Gupta *et al*[16]. use the desirability approach to optimize carpet durability by considering abrasion loss, compression and compression recovery as a single objective. Knitted fabric quality such as areal density, bursting pressure, extensibility, dimensional stability and abrasion resistance were optimized by using desirability function[17]. Asim *et al.*[18] estimated fixation of reactive printing and crease-resistant finishing using desirability function.

The present work deals with the detailed study of all the essential fabric comfort properties of handloom fabrics made up of the same warp yarn and different filling, which are made up according to mixture design from different percentages of wool, polyester and PVA. The optimization of different fabric properties is done by using the desirability function.

2 Materials and Methods

2.1 Materials

Merino wool (19.5 microns, 70 mm), polyester (1.8 den, 52 mm) and PVA (1.4 den, 44 mm) fibres were blended on the gill box in different proportions according to mixture design. Twelve wool/polyester/PVA blended yarns with linear density 20 Nm were prepared on worsted spinning system. Factors and levels of design are given in Table 1. Mixture design (Table 2) was used to investigate the proportion of different fibres on various properties of the yarn. The idea of using the mixture design is to study the effect of the proportion of different fibres and to set the proportion of the fibres according to a product with limited numbers of samples.

2.2 Dissolution of a PVA Fibre at Yarn Stage

The yarn in cone form was put in commercial dyeing machine with 0.5% formic acid at 90 ^{o}C for 60 min followed by a hot wash. Then all yarn samples were dried in an oven followed by conditioning for 24 h under standard tropical atmospheric conditions.

2.3 Fabric Formation

Twenty-four handloom fabric samples were prepared on handloom [Twelve from untreated yarn, i.e. (without dissolution of PVA) and twelve from yarns after the dissolution of PVA]. Warp yarns remained common for all the fabrics.

2.4 Dissolution of a PVA Fibre on Fabric Stage

After the production of fabric, the PVA was removed by treating the fabric (which contains PVA in their filling yarn) with 0.5% formic acid at 90 ^{o}C for 60 min, followed by a hot wash. Then all fabric samples were dried in an oven followed by conditioning for 24 h under standard tropical atmospheric conditions.

Table 1 — Levels and factors for the design

Factors	Low	Medium	High
Polyester, %	20	40	60
Merino wool, %	30	50	70
PVA, %	10	15	20

Table 2 — Blend proportions in yarn as per mixture design

Polyester, %	Merino wool, %	PVA, %
35	45	20
20	60	20
20	65	15
20	70	10
55	30	15
40	50	10
60	30	10
40	50	10
20	70	10
60	30	10
60	30	10
50	30	20

2.5 Test Methods

The samples were conditioned and tested for different fabric properties as per standards mentioned below:

The air permeability was measured using the TEXTEST FX 3300 air permeability tester, according to BS 5636 standard. Water vapour permeability (WVP) was measured according to BS 7209 standard. The water vapour permeability was calculated using the formula:

$$\text{WVP} = \frac{24M}{At} g/m^2/\text{day}$$

where M is the loss in mass (g); A, the open area of the dish (m^2); and t, the time between weighing (h).

For drying capacity measurements, 12 circular specimens per sample were cut with a round cutter, each having an area of 100 cm^2. Specimens were conditioned under standard atmospheric conditions for 6 h as per ASTM D 1776 and the weight of each sample (W_1) was recorded. The samples were then dipped in distilled water at about 10 cm depth with the help of a wire sinker. After 6 h, the specimens are taken out and kept upon a sponge sheet to dry in a closed room without any air movement. The room temperature (27±2°C) and relative humidity (65±2%) were maintained during the test. All fabrics were kept in the same condition and the face side of the specimen was kept on the upper side. After a fixed time (10 h), for all samples, the weight (W_2) of specimens were taken using the following relationship:

$$\text{Drying capacity } \left(\frac{g}{m^2}\right) = (W_2 - W_1) \times 100 \text{ (in 10 h)}$$

where W_1 is the weight of the specimen (in grams); and W_2, the weight of dried fabric.

The test to determine the stiffness of fabric was carried out according to ASTM D1388,33 using a stiffness tester. Before the tests, the samples were conditioned under laboratory conditions (25 ^{0}C, 65% relative humidity (RH)). The tests were performed on each fabric sample at five replicas in both the warp and weft directions. The equation given below was used to calculate the bending rigidities in the warp and weft directions:

$$G = Wc^3$$

where G is the fabric bending rigidity; W, the weight per unit area; and c, the bending length which is equal to half the length of the overhang:

$$G_o = (G_w G_f)^{\frac{1}{2}}$$

where G_o is the overall fabric bending rigidity; G_w, the warp bending rigidity; and, G_f, the weft bending rigidity.

To measure the compressibility of the fabric, the thickness of the fabric was measured with a thickness gauge at 20 g/cm^2 and 50 g/cm^2 pressures. The compressibility of the yarn was then calculated using the following equation:

$$\text{Compressibility (\%)} = \left[\frac{T_{20} - T_{50}}{T_{20}}\right] \times 100$$

where T_{20} and T_{50} are the thickness of fabric measured with a thickness gauge at 20 g/cm^2 and 50 g/cm^2 pressures respectively.

The thermal resistance of fabric was measured on sweating guarded hot plate thermal conductivity tester. Minimum 3 observations were made to find out average Clo value.

3 Results and Discussion

3.1 Observed Structural Changes

Scanning electron images for untreated fabric, treated fabric at yarn stage and treated fabric at fabric stage are taken to observe structural variation after dissolution of PVA component. The following observations are made from the images:

(i) The removal of the PVA component has led to creation of voids in the structure of the fabric.

(ii) The removal of PVA component after treatment at yarn as well as fabric stage leads to deformation of the fabric.

(iii) More voids are observed for a fabric having weft yarn with a higher percentage of wool after the dissolution of PVA component as compared to fabric having weft yarn having less wool content.

The creation of voids after the dissolution of PVA component influences the arrangement and configuration of fibres in yarns. This change in arrangement and configuration of fibres in yarn and fabric ultimately influence thermo – physiological characteristics of fabric.

3.2 Properties of Fabrics

Table 3 shows different properties related to thermo-physiological behaviour of fabric having treated (both at yarn and fabric stage) and untreated yarns used as weft.

Table 3 — Fabric properties before and after treatment

Fabric code	Thermal resistance Clo			Compressibility %			Air permeability $cm^3/cm^2/s$			Water vapour permeability $g/m^2/day$			Bending rigidity µNm			Drying capacity $g/m^2/10h$		
	BT	AT	ATY	BT	AT	ATY	BT	AT	ATY	BT	AT	ATY	BT	AT	ATY	BT	AT	ATY
S1	0.14	0.20	0.17	16.27	25.34	23.24	35.12	28.14	31.26	1425.5	1621.2	1522.2	204.42	181.34	190.22	187	294	266
S2	0.16	0.21	0.18	18.98	26.62	25.45	36.01	29.12	32.12	1617.2	1720.2	1689.2	213.43	187.78	195.12	211	303	272
S3	0.16	0.21	0.18	19.14	27.22	25.14	36.92	30.22	33.21	1635.3	1789.9	1702.2	215.67	187.67	198.16	211	305	272
S4	0.17	0.20	0.18	20.94	28.05	26.45	38.25	31.25	32.55	1712.2	1821.4	1798.1	203.78	194.89	200.66	223	293	279
S5	0.14	0.18	0.16	13.23	17.95	16.58	27.35	20.95	22.85	1454.7	1659.5	1523.5	183.89	169.21	175.23	190	273	254
S6	0.15	0.18	0.16	15.67	22.46	21.14	30.66	25.16	26.29	1522.2	1728.6	1672.9	188.45	161.66	169.45	197	278	246
S7	0.14	0.19	0.16	12.75	16.62	15.25	26.02	19.22	22.51	1410.5	1578.7	1510.8	192.67	170.67	181.56	191	278	255
S8	0.15	0.18	0.16	17.27	22.81	21.45	32.41	25.51	28.11	1534.4	1789.9	1622.6	187.67	172.73	179.45	197	277	257
S9	0.16	0.19	0.17	20.13	26.94	25.78	36.22	29.92	31.52	1693.8	1822.4	1757.3	201.89	193.90	200.67	207	283	264
S10	0.14	0.18	0.15	12.71	16.34	15.58	26.3	19.3	22.1	1456.9	1547.2	1523	191.34	168.45	179.78	190	275	252
S11	0.14	0.18	0.16	12.56	15.98	14.88	25.22	18.92	21.62	1447.1	1549.4	1587.2	192.43	170.23	180.90	189	272	255
S12	0.14	0.20	0.17	11.48	18.67	17.81	27.97	21.77	24.44	1456.3	1687.3	1532	206.22	172.56	184.34	191	296	257

BT, AT and ATY denote before treatment, treatment given at fabric stage treatment given at yarn stage respectively.

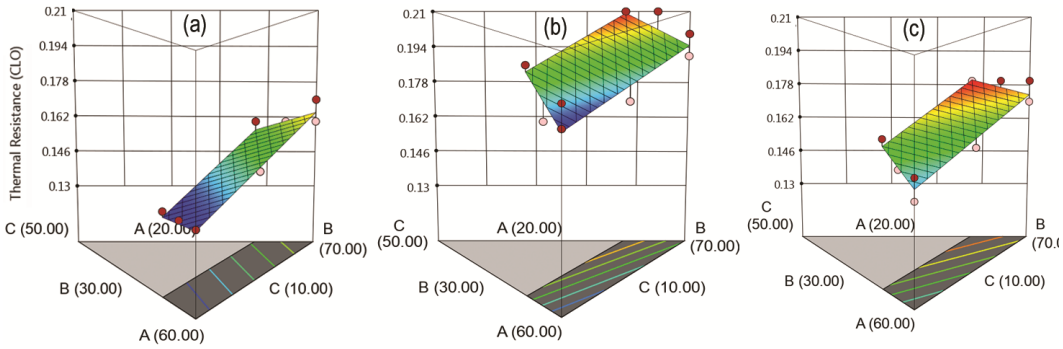

Fig. 1 — Thermal resistance of fabric before and after treatment (a) BT, (b) AT, and (c) ATY

3.2.1 Thermal Resistance

The experimental results of thermal resistance (Clo value) are given in Table 3 for both treated (at yarn stage and fabric stage) and untreated fabrics, which contain weft at a different percentage of fibres. It is observed from Figs 1 (a)-(c) that Clo value is increased with an increase in wool content in the blend for both treated and untreated fabrics. One of the major reasons for higher thermal resistance is due to the structure of wool fibre. The thermal resistance of textile material is not determined by the thermal conductivity of fibre but determined by entrapped air pockets in the structure. Higher ratio of air to fibre in the fabric structure leads to more insulation of fabric. Presence of natural crimps or curls in wool fibre helps to increase air to fibre ratio in a fabric structure, leading to the creation of air pockets and ultimately thermal resistance of fabric. Polyester being a synthetic fibre, has uniform diameter and low length variation, while wool fibre shows higher variation in length as well as diameter along its length. Such variation in wool fibre is also one of the reasons for a more open structure that leads to higher thermal resistance, with a decrease in polyester content in the fabric.

As shown in Figs 1 (a)-(c), thermal resistance of treated fabric is more as compared to untreated fabric. Textile fibres may have different ability to conduct heat, but thermal resistance of textile material is determined by the entrapped air pockets in it. After removal of the PVA component, there is creation of pores in the structure resulting in a higher value of air to fibre ratio for treated fabric as compared to untreated fabric, thus leading to more value of Clo. A higher value of Clo is obtained for fabric, which is treated at the fabric stage as compared to that treated at yarn stage. Since air is a poor conductor of heat as compared to any textile fibre, it resists the transmission of heat from fabric. Treatment at fabric stage leads to a reduction in GSM and increase in thickness, leading to more entrapment of air. Thus, it

exhibits more thermal resistance as compared to fabric made out of treated yarn.

3.2.2 Compressibility

Table 3 shows the compressibility of treated fabrics and fabrics made from untreated yarns for different percentages of fibres composition. It has been found that an increase in polyester content in blend composition leads to lower compressibility of fabric. The compression behaviour of fabric can be characterized by the bulkiness of fabric. Fabric that is bulkier and having more thickness will be compressed easily than a fabric that is less bulky and having less value of thickness. The wool fibre has crimps or curls and is resilient, which creates air pocket. This resilient characteristic of wool helps to make fabric bulkier when there is an increase in wool content, which leads to higher compression of fabric. With an increase in wool content in yarn, there is an increase in yarn diameter as well as yarn compressibility[19], which ultimately results in higher value of fabric compressibility for a fabric having a higher percentage of wool content in weft yarn.

From this study, it is also found that fabrics treated at any stage show higher compression as compared to the untreated fabric, as shown in Figs 2 (a)-(c). In treated fabric, dissolution of PVA makes yarn porous, which ultimately leads to a reduction in compactness of fabric. Therefore, the compression of the treated fabric increases after the dissolution of PVA fibre. The compressibility of treated fabric at fabric stage is higher as compared to that at yarn stage. This may be due to higher value of thickness in case of treated fabric at fabric stage as compared to that at yarn stage.

3.2.3 Air Permeability

The air permeability of fabric samples are represented in Table 3 and the surface plot for different blend composition are shown in Figs 3 (a)-(c).

All surface plots indicate that with an increase in wool content, there is an increase in air permeability. The increase in air permeability with fibre linear density can be attributed to an increase in yarn diameter with an increase in fibre linear density. In this study, wool is coarser than polyester fibre, which reduces its specific surface area with increase in its percentage. The specific surface area of fibre, being less for wool as compared to that of the the polyester fibre, can increase the air permeability of the fabric made out of it.

Table 3 shows the air permeability of both treated fabrics and fabrics from untreated yarns for different percentages of fibres composition. Less value of air

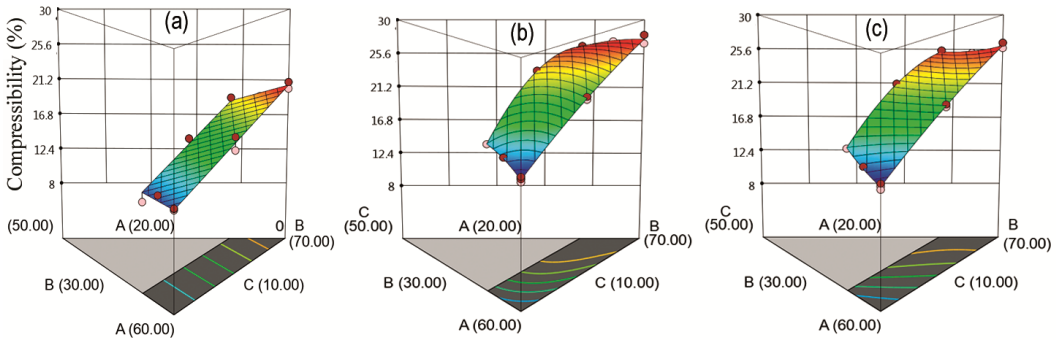

Fig. 2 — Compressibility of fabric before and after treatment (a) BT, (b) AT, and (c) ATY

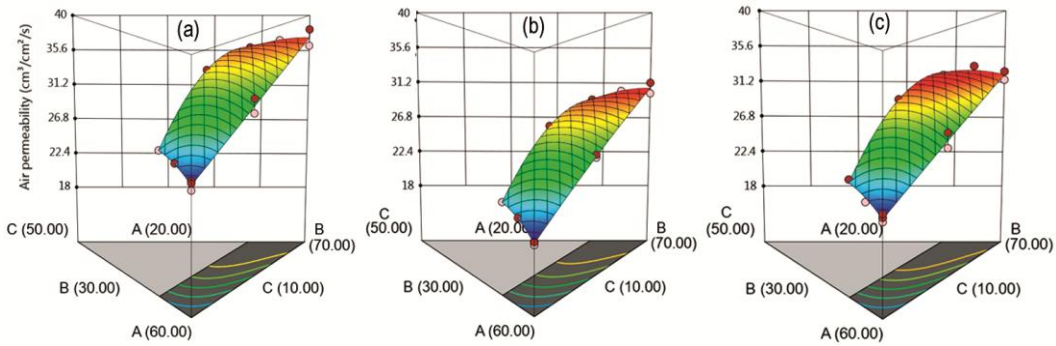

Fig. 3 — Air permeability of fabric before and after treatment (a) BT, (b) AT, and (c) ATY

permeability for treated fabric (at yarn stage) is observed as compared to untreated fabric. Similarly, the permeability is further reduced in fabric treated at fabric stage. The air permeability of fabric has a good correlation with inter-yarn porosity. The intet-yarn porosity is affected by yarn flattening or deformation in the fabric due to yarn compressibility. When a fabric is treated, both the yarn and fabric suffer deformation. After the dissolution of PVA, there is an increase in the compressibility of both yarn and fabric, which causes yarn flattening and deformation of fabric, leading to reduction in air permeability after treatment.

The compressibility of fabric after treatment at yarn stage is less as compared to that at fabric stage. This may lead to less deformation of fabric treated at yarn stage. Thus, higher value of air permeability is observed in comparison to fabric treated at fabric stage.

3.2.4 Water Vapour Permeability

It is observed from Figs 4 (a)-(c) that an increase in water vapour permeability with an increase in wool content. The diffusion rate of textile materials depends on porosity and water vapour diffusivity of the fibre for a specific concentration gradient. Diffusivity of materials is directly proportional to moisture regain. With an increase in wool percentage in blend composition, there will be an increase in overall moisture regain of the structure, which may lead to higher diffusivity. Experimental results for water vapour permeability of fabrics before and after treatment are shown in Table 3. It is observed that after the dissolution of PVA, both at the yarn stage and fabric stage, shows higher water vapour permeability as compared to untreated fabric. Transfer of vapour through fabric depends upon diffusion capillarity. The rate of diffusion from fabric depends upon pores/voids created in the structure by the dissolution of PVA from a blended yarn. After the dissolution of PVA, there is a creation of pores in yarn structure, which results in better transfer of water vapours through the diffusion process from one side to the other side of fabrics.

3.2.5 Bending Rigidity

Fabric bending rigidity is one of the important parameters which influences the handling and comfort of textile material. Surface plots for bending rigidity of fabric at different blend composition is shown in Figs 5 (a)-(c) for both treated and untreated fabrics. From Fig. 5, it is observed that with an increase in polyester content in blend composition, bending rigidity decreases up to some percentage; then, it increases for both treated and untreated yarn. As wool fibre is soft and resilient as compared to polyester,

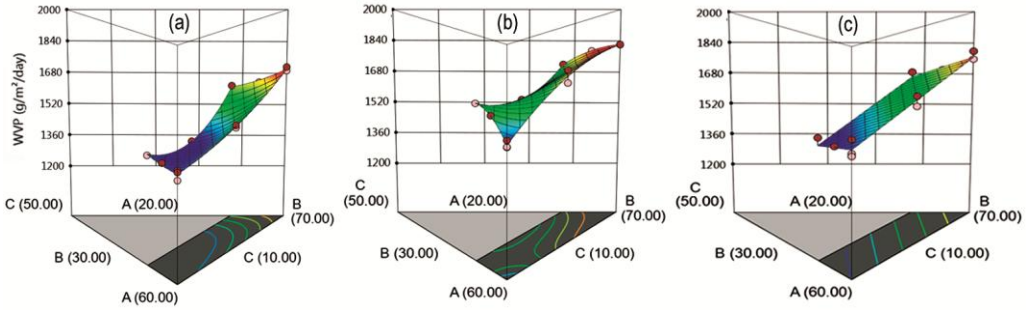

Fig. 4 — WVP of fabric before and after treatment (a) BT, (b) AT, and (c) ATY

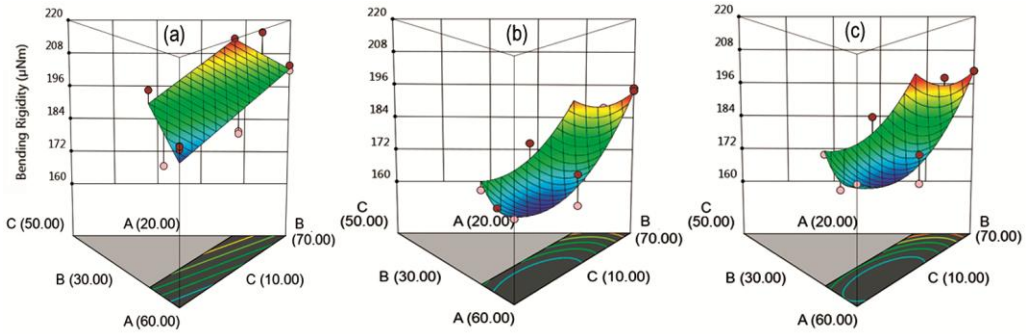

Fig. 5 — Bending rigidity of fabric before and after treatment (a) BT, (b) AT, and (c) ATY

which makes fabric stiff at high percentage of polyester. However, with an increased percentage of wool, fabric becomes stiffer as compared to fabric that contain less percentage of wool which may be due to higher linear density of wool fibre used in this study.

Experimental results showed (Table 3) for untreated and treated fabric at the yarn stage and fabric stage show that there is a reduction in bending rigidity after removal of the PVA component. Removal of PVA makes the structure relatively opens, which reduces bending rigidity. As bending rigidity of fabric depends upon bending rigidity of yarn, the finer yarn has less bending rigidity as compared to coarser yarn due to available space between fibres in the yarn. As the yarn becomes finer, the available space between yarns in the fabric also increases. After removal of PVA component, linear density of yarn (tex), decreases mean yarn becomes finer, which ultimately reduced the bending rigidity of fabric. After treatment due to the dissolution of PVA component, there is reduction in number of fibres in yarn cross-section and increase in yarn diameter results in more avialble space for the movement of fibres, which enhances the flexibility of fabric.

3.2.6 Drying Capacity

It is observed from surface plots [Figs 6 (a)-(c)] that with an increase in wool percentage in blend composition, the value of drying capacity increases. Moisture regain of wool fibre is high due to higher number of hydroxyl groups that can absorb greater mass of water as compared to polyester. Thus, the fabric having higher percentage of wool takes longer time to dry due to higher mass of water that is absorbed initially. On the other hand, polyester is hydrophobic and does not absorb water, so dry quickly.

Table 3 shows experimental results for drying capacity of both treated and untreated fabric. Results show that after the dissolution of PVA component drying capacity value increases, i.e. treated fabric take more time to dry as compared to untreated fabric. The drying capacity of fabric is influenced by the change in composition of structure that can be done either through the addition of a component or removal of a component or by some other manipulation of components. A structure that can absorb larger mass of water will have high value of drying capacity. After removal of PVA, pores are created in the structure that facilitates liquid holding/trapping capacity due to which it may take longer time to dry as compared to untreated fabric.

3.3 Optimization of Fabric Properties through Desirability Function

To overcome the problem of conflicting responses of single response optimization, multi-response optimization is used. In multi-response optimization, the desired weightage is given to all responses (equal weightage in the present study), and for a combined influence of all responses, desirability is determined for varying values of input parameters. The setting parameters, that maximize the fabric quality, are modified according to customer demands. As an example, range of input parameters and that of responses and the goal and weights assigned to each parameter for treated fabric at yarn stage, treated fabric at fabric stage and untreated fabric is presented in Table 4.

The adequate parameters to maximize the overall desirability involve the following specifications for untreated and treated fabrics, obtained by setting equal weightage to all responses:

(i) Untreated fabric

Polyester percentage= 20, Wool Percentage = 70 and PVA percentage = 10

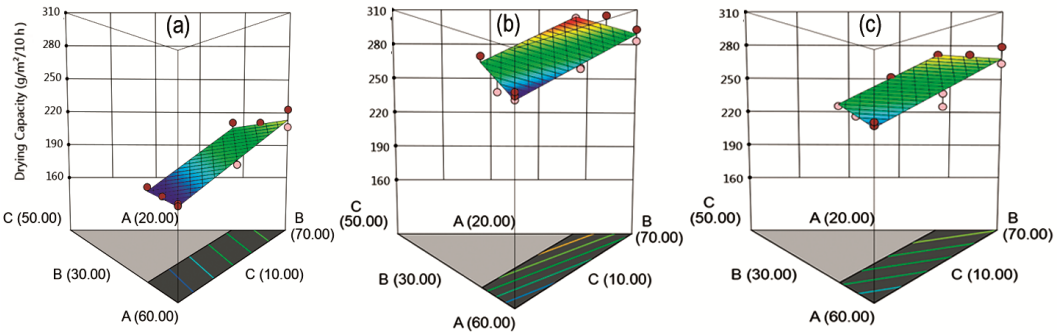

Fig. 6 — Drying capacity of fabric before and after treatment (a) BT, (b) AT, and (c) ATY

Table 4 — Response optimization of the untreated and treated fabrics

Parameter	Goal	BT Fabric		ATY Fabric		AT Fabric		Importance
		Lower limit	Upper l imit	Lower limit	Upper limit	Lower limit	Upper limit	
Poyester	In range	20	60	20	60	20	60	3
Wool	In range	30	70	30	70	30	70	3
PVA	In range	10	20	10	20	10	20	3
Air permeability	Maximize	25.22	38.25	21.62	33.21	18.82	31.25	3
Thermal resistance	Maximize	0.14	0.17	0.15	0.18	0.18	0.21	3
Water vapour permeability	Maximize	1410.5	1712.2	1510.8	1798.1	1547.2	1822.4	3
Bending rigidity	Minimize	183.89	215.67	169.45	200.67	161.66	194.89	3
Drying capacity	Minimize	187	223	246	279	272	305	3
Compressibility	Maximize	11.48	20.94	14.88	26.45	15.96	28.05	3

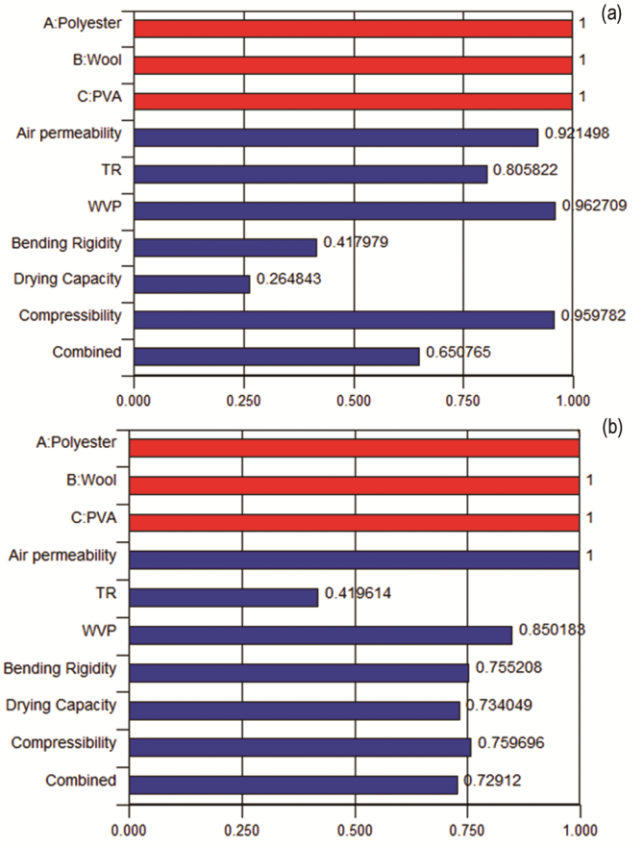

Fig. 7 — Overall desirability (a) BT, (b) AT, and (c) ATY

(ii) Treated fabric (at fabric stage)

Polyester percentage= 35, Wool Percentage = 55 and PVA percentage = 10

(iii) Treated fabric (at yarn stage)

Polyester percentage= 30, Wool Percentage = 60 and PVA percentage = 10

Figures 7 (a)-(c) show the overall desirability for untreated fabric, treated fabric at fabric stage and treated fabric at yarn stage respectively. For interpreting the desirability values Harrington's rating system has been followed. For untreated fabric, the overall desirability value is 0.65 and treated fabric at fabric stage and yarn stage are 0.72 and 0.69 respectively. In Harrington's standard, this borderline specifies that the product quality is acceptable to the specification for both treated (at yarn stage and fabric stage) and untreated fabrics. Effectively, for the treated fabric at fabric stage, the individual desirability for all responses, except thermal resistance is acceptable and excellent according to Harrington standards as shown in Fig. 7 (b). As shown in Fig. 7 (c), the individual desirability for treated fabric at yarn stage for air permeability, thermal resistance, water vapour permeability and compressibility are 0.84, 0.72, 0.70 and 0.78 respectively and also acceptable according to Harrington standards. Bending rigidity and drying capacity have 0.58 and 0.56 individual desirability values respectively that are acceptable but require some improvement. The overall desirability graph for untreated fabric [Fig. 7 (a)] show that all the responses are acceptable, but the individual desirability value of bending rigidity (0.42) requires some improvement, and drying capacity (0.25) requires more improvement.

4 Conclusion

This study deals with the effect of weft yarns having blend of polyester, wool and PVA fibres on thermo - physiological behavior of fabrics before and after dissolution of PVA component. Design expert software is used to find out the optimal value with specified desirability for both treated and untreated fabrics. The treatments given at yarn stage and fabric stage leads to the following conclusions:

4.1 The air permeability and bending rigidity of fabric are found to decrease after the dissolution of PVA component.

4.2 The thermal resistance, compressibility, water vapour permeability and drying capacity on the other hand, are found to increase due to generation of pores in yarns and fabrics after the dissolution of PVA.

4.3 Optimization of blend composition to achieve maximum desirability is done using a multi-response optimization technique that overcomes the problem of conflicting responses of single response optimization.

4.4 Equal weightage is given to all responses in this technique and overall desirability is calculated and determined for the varying percentage of different fibres.

4.5 Results of optimization for both treated fabric at yarn stage and treated fabric at fabric stage show that same/higher desirability can be achieved with lesser percentage of wool fibres in comparison to untreated fabrics.

4.6 The improvement in overall desirability can be achieved after the dissolution of PVA.

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