MODIFICATION OF WOOL BLENDED YARN FOR IMPROVED COMFORT

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Abstract: *Use of wool in active sportswear is growing rapidly. Fine and good quality woolen apparel and hosiery offer a means of enhancing performance and comfort when engaged in physical activity. The wool fibre is composed of two types of cells, viz; the internal cells or the cortex, responsible for moisture absorption and external cuticle cells that form sheath around the fibre which may cause itching, preventing its use in summer wear.With the hydrolysis of wool fibre the scale/cuticle of the fibre may be removed and wool can be more comfortable to wear even in summer. Hydrolysis by proteolytic enzymes to hydrolyze peptide bonds can be tailored to increase the removal. The fabric for active sportswear should necessarily be able to dissipate heat and moisture at high rates supported by constituent fibre and yarn for better thermo physiological responses. In this study,moisture transmission properties of knitted fabric after treatment with protease enzyme have been evaluated. Polyester/wool (90/10) yarn of 17.9 Tex (56^s Nm) was used for the study. Modification in the structure was done using two types of protease enzymes. A remarkable improvement in the moisture transportation properties and a fall in packing density and strength of the yarn were observed.*

Key Words*: Active wear, Enzyme, comfort, moisture transportation*

1. Introduction

Wool has unique elastic properties besides high moisture absorption capacity (about 35% by weight and good heat property). Low bulk density of wool leads to good heat insulation property. Proteolytic enzymes have the potential to hydrolyze the wool's peptide bonds and enzymatic hydrolysis can be tailored to increase the effect of cuticle removal for yarn structural modification [1,2].

The fabric for active sportswear/active wear are specially constructed both in terms of the geometry, packing density [3, 7, 10] and structure of constituent yarn to have significant effect on moisture transport properties [4]. Fabric with porous yarn has been reported to show higher moisture vapour transport rate [5,6]. In this study, the moisture transport behaviour of yarn and fabrics in comparison with the protease enzyme treated yarn and fabrics was investigated.

2. Material and Methods

2.1 Materials

Polyester/wool (90/10) yarn of 56^s Nm (17.9 Tex) with 8.9 twists per cm was used for the study. Polyester fibre of fineness 1.4 denier and length 56 mm &marino wool (21 µm)with average length of 70mm was used for spinning of yarn on worsted ring spinning system. Single jersey knitted fabric has been made on sock knitting machine of diameter 3.5 inches and with 22 gauge on Delha socks knitting machine. To study the effect of enzymatic treatment, two types of protease enzymes viz; acid protease (ACPE) and alkaline protease enzyme (ALPE) were used Conditioning of the yarn and fabric samples was done at 27^{o}C$\pm$2^{o}C and 65% $\pm$ 2% R.H and the number of reading was decided according to the variation in the sample so that 95% confidence limit can be achieve.

2.2 Measurement Method

2.2.1 Enzyme treatment and design of experiment

Enzyme treatment was given to yarns as well as fabrics. To avoid entanglement of yarn, hank of yarn was made with the help of wrap reel and was tied, at places, with filament.

Table 1: Actual values of variable corresponding to coded levels for alkaline and acidic protease enzyme

Variable ↓ levels →	Alkaline enzyme			Acidic enzyme		
	-1	0	+1	-1	0	+1
Enzyme% (X_1)	3	5	7	3	5	7
pH (X_2)	8	10	12	3	4.5	6
Treatment Time (min.) (X_3)	60	90	120	60	90	120

Enzyme treatment was given with three different enzyme concentration, pH value and treatment time (Table 1). The influencing parameters X_1, X_2 and X_3, are independent variables (viz; enzyme%, pH value and treatment time).

2.2.2 Evaluation of Yarn Properties

Yarn diameter was measured using a microscope(Leica) while the specific volume and packing fraction of yarn were calculated using (eq. 1, 2) the following relations [9]:

$$Yarn\ specific\ volume, \frac{cm^3}{g} = \frac{\pi d^2}{4\times10^{-5}\times tex\ of\ yarn} \quad (1), \qquad Yarn\ packing\ fraction = \frac{v_f}{v_y} \quad (2)$$

where d is the average diameter of yarn in cm, $v_f$is the specific volume (cm^3/g) ofpolyester (fibre density = 1.39 g/cm^3) and v_y is the yarn specific volume (cm^3/g).

Wicking rate of yarn was measured in accordance with DIN 53924 (1978). The rate of absorption of water (in terms of change of height of liquid/ unit time) was observed through the eyepiece of a travelling microscope. Procion Blue MR dye (1%) was added in the liquid to facilitate accuracy of reading, while maintaining the surface tension & viscosity of the liquid unchanged. The reading was taken in one minute interval up to ten minutes time. The yarn was clamped and a mass of 5g was attached to keep it straight.

2.2.3 Evaluation of Fabric properties

Water vapour permeability (eq. 3) was measured as per BS 7209 using evaporative dish method. The specimen under test was sealed over the open mouth of a dish containing water placed in the standard atmospheric condition for testing. After 24 hours the weight of the system and the rate of water vapour transfer through the fabric was calculated using the formula

$$WVP = \frac{24\times M}{At}\left(\frac{g}{m^2\times day\ of\ 24\ hrs}\right) (3)$$

M = Loss of water (gm) through fabric,A= Internal area of the fabric (m^2), t = Time of testing (24 hours)

Drying rate of the fabric was measured with the help of SDL ATLAS Drying Rate Tester using 20 x 20 cm fabric and 1ml of distilled water to wet the fabric and weight of the fabric was measured before and after 30 min time of drying and percentage loss of moisture from fabric was measured.

3. Results and Discussion

3.1 Properties of Yarns

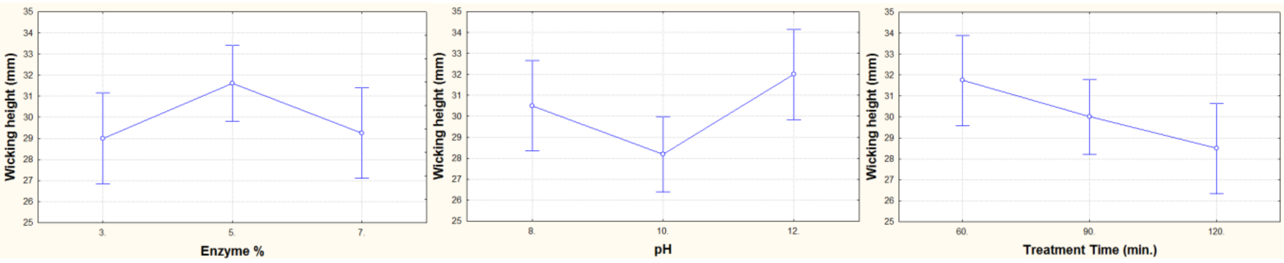
Table 2 shows the properties of yarns after alkaline and acidic enzyme treatment. It is observed that there has been considerable increase in yarn specific volume and decrease in packing fraction after enzymatic treatment in both the cases. But increase in yarn specific volume and decrease in yarn packing fraction is more in case of acidic enzyme treatment, which may be attributed to the difference in pH condition. Hydrolysis of wool fibre will be favoured in alkaline pH than to acidic pH. But if all the fibres are in contacts with each other, the yarn with lesser number of fibres in its cross-section will give better packing and lower specific volume as compared to the acidic enzyme treated yarn. In most of cases tenacity of the yarn has dropped after both type of enzyme treatment the decrease in tensile strength is probably due to hydrolysis of some wool portion and also due to decrease in the yarn packing coefficient.

Table 2 Properties of yarn before and after alkaline and acidic enzyme treatment

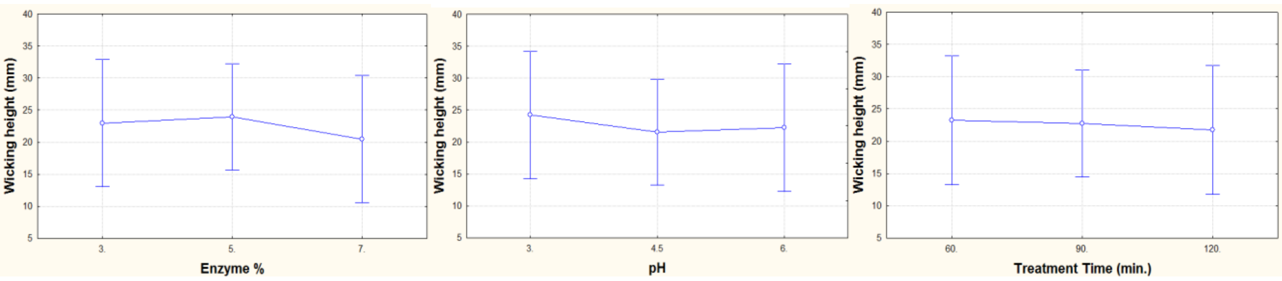
Sample No.	**Enzyme (*X*₁)**	**pH (*X*₂)**		**Treat -ment Time (*X*₃)**	**Diameter (mm)**		**Sp. Vol. cm³/g**		**Packing Fraction**		**Wicking Heigh (mm)**	
		ALPE	**ACPE**		**ALPE**	**ACPE**	**ALPE**	**ACPE**	**ALPE**	**ACPE**	**ALPE**	**ACPE**
1	3	8	3	90	0.195	0.234	1.65	2.36	0.43	0.31	29	23
2	3	12	6	90	0.193	0.238	1.69	2.4	0.43	0.30	30	21
3	7	8	3	90	0.195	0.231	1.60	2.26	0.45	0.32	28	27
4	7	12	6	90	0.185	0.234	1.55	2.3	0.46	0.31	34	19
5	5	8	3	60	0.204	0.247	1.77	2.7	0.41	0.27	35	26
6	5	12	6	60	0.186	0.243	1.54	2.61	0.47	0.28	32	25
7	5	8	3	120	0.181	0.226	1.39	2.32	0.52	0.31	30	21
8	5	12	6	120	0.196	0.235	1.72	2.53	0.42	0.28	32	24
9	3	10	4.5	60	0.189	0.232	1.51	2.25	0.48	0.32	31	26
10	7	10	4.5	60	0.193	0.246	1.60	2.85	0.45	0.25	29	16
11	3	10	4.5	120	0.195	0.227	1.62	2.39	0.44	0.30	26	22
12	7	10	4.5	120	0.183	0.234	1.44	2.34	0.50	0.31	26	20
13	5	10	4.5	90	0.185	0.248	1.45	2.62	0.50	0.27	29	21
14	5	10	4.5	90	0.186	0.236	1.48	2.39	0.49	0.30	30	29
15	5	10	4.5	90	0.186	0.245	1.50	2.59	0.48	0.28	28	21
Avg.					**0.190**	**0.237**	**1.57**	**2.46**	**0.46**	**0.29**	**30**	**23**
Untreate Sample					**0.176**		**1.33**		**0.54**		**35**	

3.2 Wicking in Yarn

In order to keep the body dry, the fabric must be able to transport moisture away from the skin either through diffusion of wicking. Physically wicking is the spontaneous flow of a liquid in a porous substrate, driven by capillary forces[8].Mean plot of wicking behaviour of alkaline protease and acidic protease enzyme treated yarn has been shown in figure 1. Wicking height of treated yarns is lower than the untreated yarn as shown in table 2. It is observed from the figure 1 (a), that middle level of the enzyme concentration gives higher wicking height than lower and higher level. In case of pH, higher level gives highest wicking than central and lower level. Wicking decreases after treatment presumably due dissolution/partial dissolution of wool fibre which reduce the packing density of yarn. In case of treatment time, wicking decreases with increase in treatment time. In case of acidic treatment figure 1 (b), enzyme concentration, pH and Treatment time does not show much influence as in the case of alkaline enzyme treatment.Wicking is less in acidic treated yarn as compared to alkaline treated and untreated yarn.This is due to the reduction of packing density of yarn with partial dissolution of wool fibre.The wicking behaviour of yarn in both treatments is mainly affected by the enzyme concentration and pH value, as can be observed from the response surface equation in Table 3.



(a)



(b)

Figure 1: Mean plot of the yarn wicking after (a) alkaline and (b) acidic enzyme treated yarn

Table 3 Regression equations for Moisture Transport properties

Properties (*Y*)	**Response Surface Equations**	R^2
Wicking (yarn)	$-123.31+34.25*x_1-1.44*x_1^2+33.84*x_2-1.63*x_2^2-6.25*x_1*x_2-13.31$	0.98 (Alkaline)
	$-13.73+7.46*x_1+19.67*x_2-3.48*x_2^2-2.50*x_1*x_2+.78*x_1*x_2^2+4.880.74$ (Acidic)	
Water Vapour Permeability	$-3443.56+36.60*x_1-5.63*x_1^2+647.73*x_2-33.44*x_2^2+26.08*x_1*x_2-2.58*x_1^2*x_2-1.97*x_3.*x_1+933.45$	0.99 (Alkaline)
	$-1681.58+520.49*x_1-49.88*x_1^2+369.45*x_2-41.20*x_2^2-3.26*x_1*x_2-5.14*x_3.*x_1+1480.46$	0.99 (Acidic)
Dry Rate %/min	$1.69-0.22*x_1-0.10*x_2+0.10*x_2^2+0.24*x_1*x_2+0.36$	0.86 (Alkaline)
	$2.67-0.59*x_1-1.14*x_2+0.13*x_2^2+0.18*x_1*x_2 0.21$	0.99 (Acidic)

Note: Insignificant terms appeared in the equations were ignored

3.3 Properties of knitted fabric

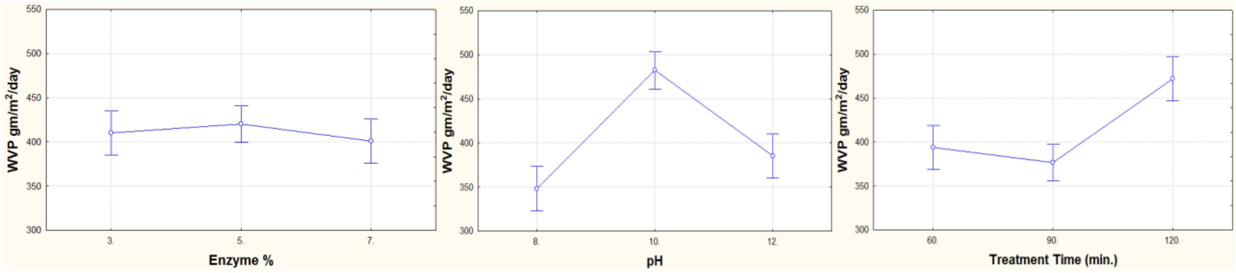
The fabric thickness has been found to increase after both alkaline and acidic protease enzyme treatment while the air permeability (shown in Table 4) of the fabrics was found to reduce. Due to the enzyme treatment, removal of wool component generates additional voids in the structure which allow readjustment of the fibres in the structure which has been manifested as shrinkage. Such readjustment of fibres in the structure is also expected to be assisted by the relaxation of the fibres from the applied stress during twisting. Yarn diameter, structure of yarn and fabric construction can affect the air permeability of a fabric. Reduction in air permeability in the present study may be attributed to the increased bulk of yarn structure of treated assembly blocking inter yarn spaces in fabric.

3.4 Water Vapour Permeability (WVP)

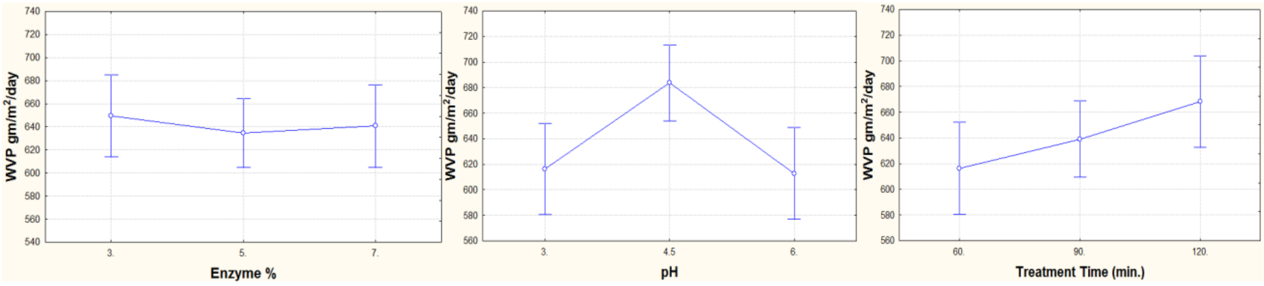
The ability of a fabric to transmit the water vapour emitted from the body is an important factor in assessing in the comfort characteristicsof fabrics and clothing assemblies, as it represents ability to transfer perspiration coming out of the body. As can be seen from the mean plot of figure2 and Table 4 the relative water vapour permeability of acidic enzyme treated fabric is higher than alkaline treated fabric and untreated fabric. From figure 2(a) it is observed that the with increasing enzyme concentration and pH the water vapour permeability increases up to middle level and then decreases. In case of treatment the case is reverse the water vapour permeability from lower to middle level decrease and from middle tohigher level it is increases. In case of acidic enzyme [figure 2 (b)], with increasing enzyme concentration water vapour permeability decreases. With increasing pH value the value of water vapour permeability increase upto middle level and from middle to higher it is decreases. In case of treatment of time the water permeability increases as time increases from lower to higher level. Yarn character plays an important role in transmission of water. Open structure allows more water vapour transmission. Increase in water vapour permeability may be attributed to bulky structure of treated yarn assemblies in knitted structure. Bulky structure allows water to transfer from inside to outside through diffusion. The water vapourin both treatments is mainly affected by the enzyme concentration and pH value, as can be observed from the response surface equation in table 3.

Table 4: Water vapour permeability of alkaline (a) and acidic (b) protease enzyme treated fabric

	Water Vapour **Permeability (g/m^2/day)**														
Sample type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
ALPE	346	341	317	354	310	424	420	422	427	414	526	519	512	526	536
ACPE	625	616	615	614	613	619	613	603	614	621	744	713	722	724	733
Untreated sample	243														
	Air permeability$cm^3/cm^2/s$														
ALPE	180	215	82	63	85	77	81	195	200	186	199	186	187	201	198.7
ACPE	312	274	281	278	278	343	339	310	357	383	285	288	267	275	266.5



(a)

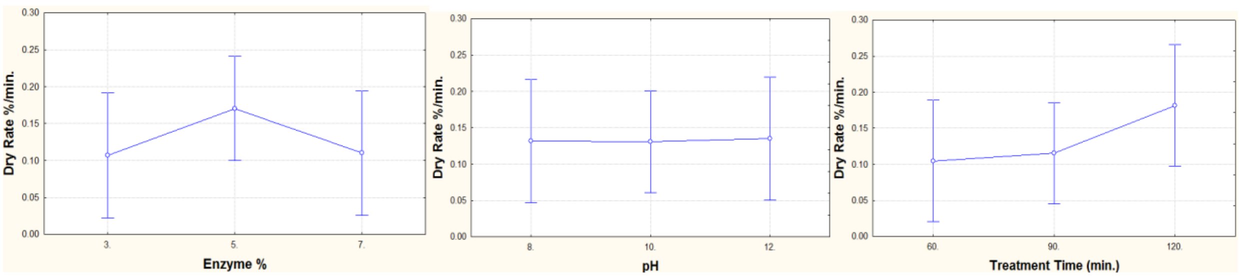


(b)

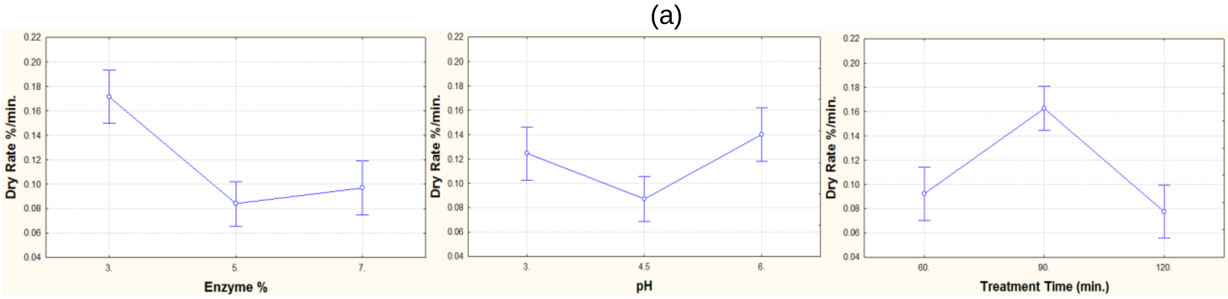
Figure 2: Mean plot of the yarn wicking height after (a) alkaline and (b) acidic enzyme treated fabric

3.5 Drying Behaviour of Fabric

In order to increase the comfort level of the wearer, the absorbed moisture must be dissipated to atmosphere. A faster drying rate will ensure better thermo physiological comfort. The drying rate%/min is an important parameter to assess the drying behaviour of a fabric. From Table 5, it is observed that the rate of drying of alkaline protease enzyme treated fabric is the highest. The mean plot of dry rate%/min is given in figure 3. It is observed that the drying rate of alkaline enzymetreated fabric initially increases and then decreases while the same decreases consistently for acidic enzyme treated fabric. A change in pH value does not show much effect in alkaline enzyme treatment results in initial fall and then rises. Treatment time in alkaline enzyme treated fabric causes constituent increases in drying rate while acidic enzyme treated result in initial rise up to middle level and than a fall. The dry rate of the fabric can be explained on the basis of the nature of wicking behaviour of the fabric as greater wicking leads to quicker spreading of water, which assist in faster drying. In case of untreated fabric with presence of wool fibre, the water cannot evaporate easily, which absorbed by fibre. Acidic enzyme treated fabric has lowest packing density of yarn, which give open yarn structure, so more volume of water can be absorb by the fibrous assembly and hence lower dry rate.



(a)



(b)

Figure 3: Mean plot of the dry rate %/min. after (a) alkaline and (b) acidic enzyme treated fabric

Table 5: Dry rate of the alkaline and acidic protease enzyme treated fabric

Prop-erties	**S. No.**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Dry rate %/min	**ALPE**	0.14	0.15	0.09	0.02	0.14	0.157	0.16	0.22	0.05	0.07	0.08	0.27	0.2	0.19	0.11
	ACPE	0.27	0.26	0.05	0.13	0.08	0.09	0.09	0.08	0.09	0.12	0.06	0.08	0.1	0.08	0.08
Untreated fabric		0.104														

4. Conclusion

In present study an attempt was made to study the moisture transportation characteristics of fabrics from modified structure of worsted yarn. After treatment it was found that the diameter, specific volume have been increases and packing density of yarn has been reduces in both the cases. Single jersey Knitted fabric made with different polyester/wool blended yarn, treated with two types of protease enzyme has different moisture transport behaviour. Yarn characteristics have significant influence on the moisture transport properties of the fabrics. Both treated fabric possess better moisture transport properties than untreated fabric. Wicking in yarns treated with two different enzymes was found to be less in comparison to untreated yarns.The alkaline protease enzyme shows better moisture vapour permeability and dry rate of the fabric. Acidic protease enzyme fabric shows better moisture vapour permeability. Among the three fabric alkaline protease enzyme treated fabric is terms of moisture transport properties and dry rate of the fabric.

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