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Study on Improvement in Handle Properties of Wool/Cotton Union Fabric by Enzyme Treatment and Subsequent Polysiloxane-based Combination Finishing

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ABSTRACT
The present study presents the effect of protease/lipase enzyme pretreatment followed by polysiloxane based combination finishing on handle properties of wool: cotton union was studied. Union fabric was pre-treated with Savinase 16.0L Ex/Lipolase 100T enzyme individually, followed by finishing with six different polysiloxane based combinations by pad-dry-cure method. The moisture property, handle property and mechanical properties of finished and unfinished were evaluated as per standard procedure. The results inferred that both enzymes improve the handle of the union fabric irrespective of their nature and subsequent combination finishing further improves the handle. The extent of improvement depends on the nature of finishing combination applied, in which combination of nano, micro, macro polysiloxane with a cationic softener (Sandoperm-SE1+Ceraperm-MW+Ceraperm-UP+Sandosoft-SPG) on Savinase treated fabric shows better hand value (3.3) than others (<3.1). It is concluded that combination finish on Savinase treated union fabric imparts better handle properties than corresponding Lipolase treated ones and finished-only fabrics.

Key words: Hand value, lipase, moisture, protease, softness

INTRODUCTION
The hydrophobic nature of the wool fiber is due to the presence of covalently bound lipids on the surface of the cuticle membrane (Evans *et al.*, 1985). The hydrophobic surface of wool is a desirable attribute in finished textiles but presents processing difficulties where the spreading and adhesion of chemical finishes to the fiber surface is required. In practice, this can be achieved by chemical treatment such as strong alkali, chlorine or plasma treatments that remove some of the surface bound fatty acids (Corfield *et al.*, 1967; Negri *et al.*, 1993; Shao *et al.*, 1997). Such processes generate polar functional groups on the surface of the fiber with a concomitant increase in surface free energy, thus providing the driving force for the spreading and adhesion of finishing agents.

Chemical treatments can however, result in damage to the whole fiber, which may adversely affect handle properties and release hazardous chemicals into the environment. The use of enzymes for wool surface modification is a possible solution to these problems and has attracted considerable interest in recent years (Nierstrasz and Warmoeskerken, 2003; Shumi *et al.*, 2004). The majority of this research has been directed towards shrink-resist and softening treatments using proteolytic enzymes (Heine and Hocker, 1995) and relatively few studies have examined the use of esterases to hydrolyze ester- or thioester-bound fatty acids from the fiber surface.

Lipase a type of esterase hydrolyses triacylglycerol and giving a discyl glycerol and fatty acid anion. The hydrolytic reaction of lipase resembles some proteases (Pahoja and Sethar, 2002; Hutchinson *et al*., 2007). Heine (1991) first investigated the action of a lipoprotein lipase on the surface of wool. A pre-treatment of wool top with a lipase enzyme from Novozyme was investigated by El-Sayed *et al*. (2000, 2001) in the development of a zero-AOX shrink-resist process. The lipase treatment was the first of four-steps that included lipase, oxidation with sodium monoperoxyphthalate, reduction with sodium sulfite and finally, treatment with papain. Kantouch *et al*. (2005) inferred that lipase pretreatment on wool fabric removes dye barrier on the wool fiber surface and improves the dye uptake of anionic dyes. Lipase was also used to hydrolyze ester linkage on the surface of the polyester fiber in order to improve its hydrophilicity (Hsieh and Cram, 1998). The application of enzymes on textiles to improve its softness had greater attention since 1970's.

Shridhar *et al*. (1995) improved the softness of wool: cotton blended fabric by treating them with cellulase enzyme successively with protease enzyme with favorable changes in the physical and handle properties. Polysiloxanes have been used to formulate textile softening since 1960's. Cationic softener provides a very silky hand and improves the antistatic properties of the fabric. Many studies revealed that chemical finishes cause significant changes in performance properties of a fabric such as softness of cotton (Hashem *et al*., 2009), wool (Feldman and Felischfresser, 1975) and wool/cotton (Harper and Mehta, 1985) blended fabrics. Prior protease enzyme (Savinase 16.0L Ex) treatment followed by cationic softener, micro and macro polysiloxane (Sandosoft-SPG+Ceraperm-MW+Ceraperm-UP) combination finishing on wool/cotton union fabric showed better handle properties in terms of softness and total hand value than their individual application (Ammayappan, 2008). The combination of different types of softening agents imparts variation in soft handle with technical or functional requirements such as hydrophilicity, elasticity, durability, sewability etc. (Wable and Falkowski, 2002). Rocco (2010) developed technical textiles from regenerated wool and improved their aesthetic properties by finishing with fluorocarbon.

The literature review reveals a void in research on the effect of prior enzyme treatment on finishing of wool-based fabric with cationic softener, micro and macro polysiloxane combination finishing. This paper illustrates the effect of prior lipolytic and proteolytic enzyme treatment followed by combination finishing of cationic softener, micro and macro polysiloxane in different formulation on wool/cotton union fabric.

MATERIALS AND METHODS

Wool/cotton union fabric: Central Sheep and Wool Research Institute, India (CSWRI) had developed wool/cotton union fabrics of different specifications from Bharat merino woolen yarn as weft and cotton yarn as warp (Anonymous, 2006) and fabric of the following specifications was taken for this study; 40 EPI, 16 PPI, 2/2 twill weave, 363 g m^{-2}, 2/15's cotton warp, 2.75 Nm wool weft, 1.52 mm thickness and fiber ratio as wool: cotton (66:34).

This research work was a part of the project named Study on Improvement in Aesthetic Properties of Woolen Products by Different Chemical Finishes during the period from 31st March 2006 to 30th June 2006 at Department of Chemistry, PSG College of Technology, Coimbatore-643003, India.

Table 1: Details of enzymes used

Enzyme	EC No	Source	Declared activity
Savinase- 16.0L Ex	E.C.3.4.21.62	Novozymes South Asia Pvt. Ltd., India	16 KNPU mg^{-1}
Lipolase-100T	E.C.3.1.1.3	Zydex Corporation Mumbai, India	100 KLU mg^{-1}

Enzymes: The enzymes used for this study were given in Table 1. Based on the composition of wool and cotton in the union fabric and on enzyme manufacturer's technical information, the concentration of and protease enzyme used for this union fabric was optimized by taking various trails. The optimum concentration of Savinase-16.0L Ex (alkali stable protease enzyme) and Lipolase-100T (lipolytic enzyme) used for this fabric were 2 and 3% over the weight of wool portion (oww), respectively.

Finishing chemicals: The finishing chemicals used for this study were supplied by Clariant Chemicals (India) Ltd., Mumbai, India. They were Ceraperm-MW (modified micro polysiloxane), Sandosoft-SPG (Cationic softener), Ceraperm-UP (modified macro polysiloxane), Sandoperm-SE1 (nano polysiloxane), Sandoperm-RPU (Polyurethane based softener) and Ceraperm-TOWI (nano polysiloxane). All other chemicals used elsewhere were AR grade.

Methods: The wool/cotton union fabric was treated with Lipolase-100T and Savinase 16.0L Ex separately, then the untreated and enzymes treated fabrics were treated with six different finishing combinations form by pad→dry→cure method.

Enzyme treatment: The wool/cotton union fabric was treated with Savinase-16.0L Ex (Enzyme-2% (oww); pH 8.5 with sodium carbonate; 30 min; 50°C; 1:20 MLR; Sandoclean PCJ-0.1 gpl) and Lipolase-100 T (Enzyme-3% (oww); pH 9.5 with sodium carbonate; 60 min; 55°C; 1:20 MLR; Sandoclean PCJ-0.1gpl) separately, neutralized with 0.25% acetic acid, washed with water and dried.

Finishing treatment: The untreated and enzyme treated union fabric were treated with selective six finishing combinations as per recipe given in Table 2, along with finishing chemicals 0.5 gpl Sandoclean PCJ was added and the pH was adjusted to 5.0 with 0.5 mlpl acetic acid solution. Fabric of 35×35 cm dimension was impregnated in the finishing bath for two minutes and padded with 80% expression under 1.5 kg cm^{-2} using a laboratory padder (R.B. Engineering Ltd., Gujarat, India). The padded fabrics were dried at 100°C in an air oven (R.B.Engineering Ltd., Gujarat, India) followed by cured at 150°C for 3 min in high temperature steamer (R.B. Engineering Ltd., Gujarat, India), washed with distilled water and dried.

Evaluation of performance properties: The finished and unfinished fabrics with and without prior enzyme treatments were conditioned under standard condition (20±2°C, 65±2 %RH, 4 h) and the following performance properties were evaluated as per established standard: moisture regain (ASTM, 2001a), wettability (BSI, 1973a, b), wicking height (Harnett and Mehta, 1984), drape coefficient (BSI, 1990), subjective assessment (Zochairah *et al.*, 1997), bending length (BSI, 1990) dry crease recovery angle (AATCC, 2003), tearing strength (ASTM, 2001b) and primary and total hand value for winter suiting fabric by Kawabata hand evaluation system (KES-F) (Kawabata, 1980).

Table 2: Recipe of combination finishing treatment

Recipe	Abbreviation
Unfinished	Unfinished (E0)
Sandosoft-SPG = 50 gpl	
Ceraperm-MW = 30 gpl	
Sandoperm-SE1 = 10 gpl	S-SPG+C-MW+S-SE1 (E1)
Sandosoft-SPG = 50 gpl	
Ceraperm-MW = 30 gpl	
Ceraperm-TOWI = 30 gpl	S-SPG+C-MW+C-TOWI (E2)
Sandosoft-SPG = 50 gpl	
Ceraperm-MW = 30 gpl	
Sandoperm-RPU = 25 gpl	S-SPG+C-MW+S-RPU (E3)
Sandosoft-SPG = 50 gpl	
Ceraperm-MW = 30 gpl	
Ceraperm-UP = 30 gpl	S-SPG+C-MW+C-UP (E4)
Sandosoft-SPG = 50 gpl	
Sandoperm-SE1 = 10 gpl	
Ceraperm-UP = 30 gpl	S-SPG+S-SE1+C-UP (E5)
Sandosoft-SPG = 50 gpl	
Ceraperm-MW = 30 gpl	
Sandoperm-SE1 = 10 gpl	
Ceraperm-UP = 10 gpl	S-SPG+C-MW+S-SE1+C-UP (E6)

RESULTS AND DISCUSSION

The wool/cotton union fabric is treated with Savinase 16.0L-Ex and Lipolase-100T separately and then subsequently treated with combination of cationic softener, nano, and micro and macro polysiloxane emulsion in six different formulations. The performance properties of finished and unfinished fabrics with and without prior enzyme treatment were evaluated and compared with untreated fabric (E0).

Finish add-on: The added finish on untreated and Savinase 16.0 L-Ex/Lipolase-100T enzyme treated wool/cotton union fabric is given in Table 3, it is observed that the mean finish add-on in Lipolase treated fabrics (5.3%) and Savinase treated fabrics (3.8%) are higher than non-enzyme treated ones (2.8%); and inferred that both enzymes had a significant effect on spreading and adhesion of finishing polymer. It is also attributed that Lipolytic enzyme modifies both cotton and wool fibrous substrates (Monlleo *et al.*, 1994; Achwal, 1993), which resulted in higher spreading and adhesion of finishing chemical on this fabric than protease enzyme treated ones.

Moisture regain: The moisture regain of finished and unfinished wool/cotton union fabric with and without prior enzyme treatment is given Fig. 1, there is a slight difference in moisture regain, wettability and wicking height between these two enzymes treated fabrics and their corresponding finished fabrics. These parameters are higher in Lipolase treated fabrics than Savinase treated ones. These two enzyme treatment improve the moisture regain of the fabric, while after finishing it is reduced when compared with untreated fabric (11.8%). However enzyme treated and finished fabrics are regained more moisture than finished only fabrics, which is due to the formation of new functional groups by the enzymatic action and/or removal of hydrophobic layer on fiber surface (Walawska *et al.*, 2006). The mean reduction in moisture regain is higher in Savinase treated and

Table 3: Added finish(%) on untreated and enzyme treated wool/cotton union fabric

	Enzyme treatment		
Finishing formulation	UT	SAV	LIP
EO	0.00	-3.43	-3.56
E1	1.71	2.79	4.59
E2	3.02	4.13	5.72
E3	3.51	4.49	5.75
E4	1.62	2.65	4.36
E5	3.21	4.00	4.99
E6	3.82	4.84	6.14

UT: Untreated; SAV- Savinase 16.0 L Ex treated; LIP: Lipolase 100 T treated

Table 4: Wettability (sec) of finished and unfinished wool/cotton union fabrics with and without prior enzyme treatment

	Enzyme treatment		
Finishing formulation	UT	SAV	LIP
EO	60	18	20
E1	58	40	36
E2	59	35	42
E3	38	18	17
E4	204	193	175
E5	73	45	61
E6	42	24	20

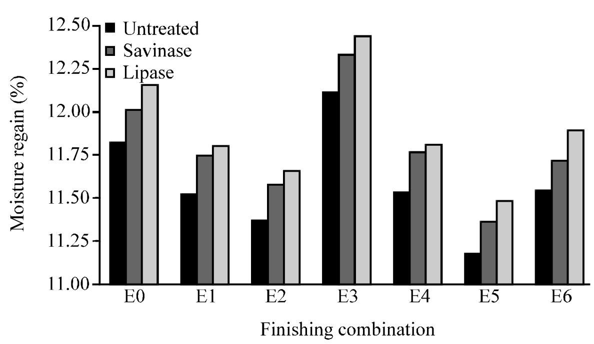

Fig. 1: Moisture regain (%) of finished and unfinished wool/cotton union fabric with and without prior enzyme treatment

finished fabrics (11.76%) than Lipolase treated ones (11.83%). The Sandoperm-RPU based finished fabrics regained more moisture than other finished fabrics due to presence of hydroxyl functional groups in this polymer.

Wettability: The wettability of finished and unfinished wool/cotton union fabric with and without prior enzyme treatments is given in Table 4. It is observed that the wettability of finished and unfinished fabrics resembles the moisture regain property as discussed in the above and the wettability is better in S-RPU combination finished fabrics (<18 sec) than other combination finished fabrics (>20 sec). During finishing of polymer blends of hydrophilic polymer and

Table 5: Wicking height(mm) of finished and unfinished wool/cotton union fabric with and without prior enzyme treatment

	Enzyme treatment					
	Warp			Weft		
Finishing formulation	UT	SAV	LIP	UT	SAV	LIP
EO	4	9	12	4	19	16
E1	39	56	54	6	14	25
E2	34	47	54	26	54	44
E3	55	69	74	18	39	44
E4	9	24	17	6	8	12
E5	33	53	46	5	9	24
E6	48	63	66	31	40	48

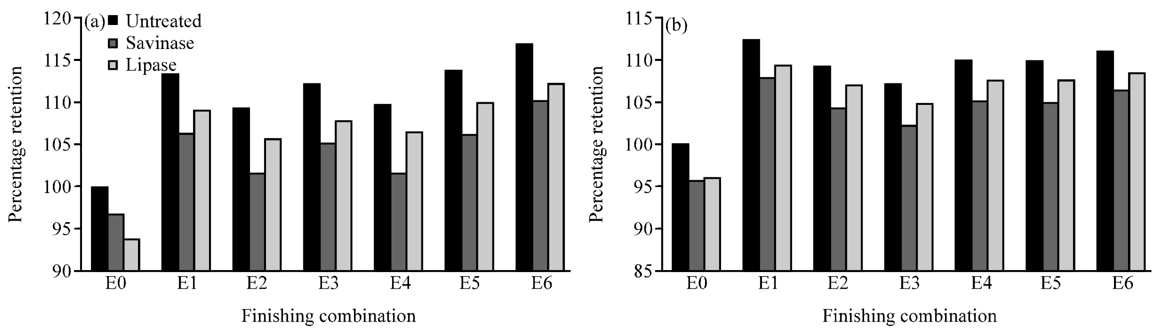

Fig. 2: Retention of tearing strength (%) of finished and unfinished wool/cotton union fabric with and without prior enzyme treatment. (a) Warp direction and (b) weft direction

hydrophobic polysiloxane, the silicone component moved to the surface during drying ensuring the surface exhibits lowest energy possible and reduces wettability (Hebereder and Bereck, 2002). This explanation is in agreement with the experimental data obtained.

Wickability: The wicking height of finished and unfinished wool/cotton union fabric with and without prior enzyme treatments is given in Table 5. The wicking height of untreated fabric is very low (4 mm) in both directions, after each enzyme treatments weft direction wicks more moisture than warp direction, while after finishing it is improved in both directions in which the warp direction (mean 39 mm) wicks more moisture than weft direction (mean 15 mm). The Lipolase treated and E3 combination finished fabric wicks more moisture than other finished fabrics in both directions. It is inferred that S-SE1/C-TOWI/S-RPU based combination finishing (up to 74 mm) on this fabric wicks more moisture than their absence (up to 24 mm).

Tearing strength: The retention of tearing strength of finished and unfinished wool/cotton union fabric with and without prior enzyme treatment in warp and weft direction is given in Fig. 2a and b. The tearing strength of fabric is reduced after both enzymatic treatment and the reduction is higher in weft direction (96%) than warp direction (97%) in Savinase treated fabric and vice versa in lipolase treatment (96 and 94%). After finishing Savinase treated fabrics are retained their tearing strength better in weft direction (from 103 to 108%) than warp direction (from 102 to

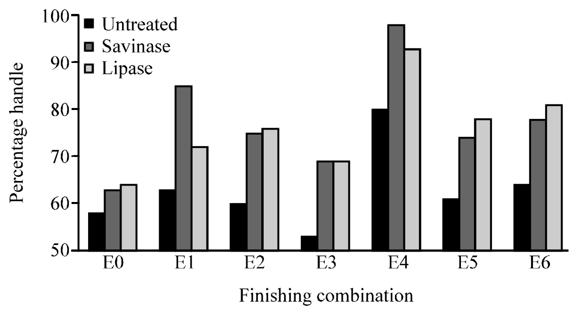

Fig. 3: Handle (%) of finished and unfinished wool/cotton union fabric with and without prior enzyme treatment

110%), while in Lipolase treated fabrics it is better in warp direction (from 106 to 112%) than weft direction (105 to 109%). The maximum retention is observed in enzyme treated and E6 combination finished fabrics both in warp (115%) and weft (112%) direction. The adhered polymers from E6 finishing combination improve the mobility of component fibers of this fabric as they can absorb and dissipate the mechanical energy, which results in improvement in tearing resistance (Hardt, 1984; Azad *et al.*, 2007).

Subjective assessment: The handle in terms of softness of finished and unfinished wool/cotton union fabric with and without prior enzyme treatment evaluated by subjective assessment is given in Fig. 3. The exhaustion of polysiloxane emulsion into a fiber is based on their size (such as nano, micro and macro emulsion) and the exhausted polymer imparts softness of varied degree, which depends on its emulsified size. Nano polysiloxane emulsion adheres on the fiber surface, diffuses and fixes into the fibrous matrix and imparts inner softness with very good absorbency; micro polysiloxane imparts inner feel and softness and macro polysiloxane fixes on the fibrous surface and imparts permanent smoothness and bulkiness (Mooney, 2003; Heberedar *et al.*, 1993; Holzdorfer, 2001; Celik *et al.*, 2010).

Judges felted that the softness of untreated fabric is moderate and both enzyme treatments impart uniform softness feel and inferred that there is no significant difference in softness between these two enzymes treated and finished fabrics. However Savinase treated and E1 or E4 combination finished fabrics are showed better softness (87 and 98%) than corresponding Lipolase treated ones (72 and 93%). The combined application of polysiloxane emulsions with a cationic softener could provide a soft silky hand and improves the handle of a fabric, while the application of nano, micro and macro polysiloxane with cationic softener (E6) impart moderate softness on both untreated and enzyme treated fabrics.

Objective assessment by KES-F

Primary hand value: The primary hand value in terms of smoothness (Numerii), stiffness (Koshi) and fullness (Fukurami) for winter suiting fabric evaluated from sixteen parameters evaluated of KES-F is given in Table 6. It is observed that, the untreated fabric has low smoothness and moderate stiffness and fullness; after both enzyme treatments, smoothness is improved from 1.6 to 3.2, stiffness is reduced slightly from 5.6 to 5.3 and fullness is improved from 4.3 to 5.7. The Savinase treated and finished fabrics showed better improvement in smoothness and fullness value than corresponding Lipolase treated ones and the improvement depends on finishing combination

Table 6: Primary hand value of finished and unfinished wool/cotton union fabric with and without prior enzyme treatment

		Enzyme treatment		
PHV	Finishing formulation	UT	SAV	LIP
Smoothness (Numerii)	EO	1.6	3.2	2.8
	E1	4.2	4.6	4.7
	E2	3.7	4.2	3.9
	E3	3.8	4.3	4.1
	E4	2.9	6.2	4.6
	E5	4.2	4.6	4.3
	E6	4.9	5.4	5.2
Stiffness (Koshi)	EO	5.6	5.3	5.3
	E1	4.5	4.8	4.3
	E2	5.2	5.0	5.5
	E3	4.7	4.9	4.4
	E4	6.4	5.3	5.9
	E5	4.5	4.6	4.4
	E6	4.5	4.5	4.9
Fullness (Fukurami)	EO	4.3	5.7	5.7
	E1	5.9	5.9	6.8
	E2	6.0	6.4	6.6
	E3	6.1	6.2	6.2
	E4	4.8	9.7	7.0
	E5	6.5	7.1	6.2
	E6	6.4	6.9	7.4

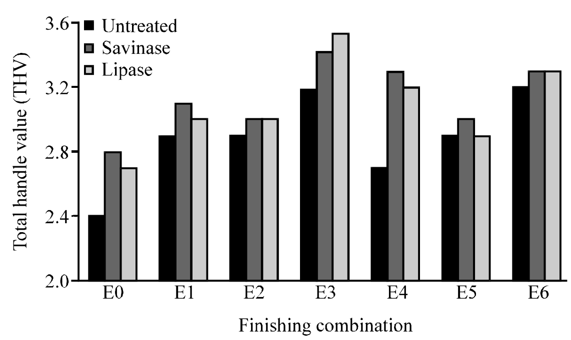

Fig. 4: Total hand value of finished and unfinished wool/cotton union fabric with and without prior enzyme treatment

applied. The enzyme treated and finished fabrics are shown a slight improvement in primary hand values, when compared to finished-only fabrics. For example E1 combination finishing on Lipolase enzyme treated fabric is improved smoothness value from 4.2 to 4.7 and fullness value from 5.9 to 6.8, respectively. It is attributed that at higher finishing chemical formulations, the enzyme treatment had only little significant effect on the handle of the fabric.

Total hand value: The Total Hand Value (THV) of finished and unfinished wool/cotton union fabric with and without prior enzyme treatment is given in Fig. 4. The above primary hand value trend is also observed in total hand value. The THV of untreated fabric is moderate (2.4) and is

Table 7: Bending length (mm) of finished and unfinished wool/cotton union fabric with and without prior enzyme treatment

	Enzyme treatment					
	Warp (C_w)			Weft (C_f)		
Finishing formulation	UT	SAV	LIP	UT	SAV	LIP
EO	15.0	14.7	14.4	15.2	14.8	14.4
E1	13.9	13.4	13.7	14.0	13.5	13.9
E2	13.3	13.0	12.9	13.9	13.5	13.6
E3	14.7	14.5	14.1	14.7	14.3	14.3
E4	14.1	13.7	13.8	14.2	13.8	13.9
E5	14.5	14.2	14.2	14.4	14.2	13.9
E6	13.8	13.4	13.5	13.8	13.4	13.4

improved subsequently after each enzyme treatment followed by finishing. Savinase enzyme treated and E6 combination finished fabric showed maximum THV (3.3) than other finished fabrics. The THV of Savinase treated and finished fabrics are slightly higher than corresponding Lipolase treated ones. Kawabata and Niwa (1996) inferred that when the hand value of a sample falls into high-quality zone (THV from 3.5 to 5.0), it is evaluated as a high-quality winter suiting fabric (Kawabata and Niwa, 1996). From our experimental results, it is inferred that prior enzyme treatment and subsequent combination finishing made this fabric suitable for medium-quality winter fabric.

Bending stiffness: The bending length of finished and unfinished wool/cotton union fabric with and without prior enzyme treatment is given in Table 7. The bending length of untreated fabric in warp and weft directions is 15.0 and 15.2 mm, respectively, which is significantly reduced after enzyme treatment and further in all combination finishing treatments. The reduction in stiffness results from a reduction in fiber bending stiffness caused by enzymatic modification of its structure (Mall *et al.*, 2002). The enzyme treated and finished fabrics are shown better reduction in bending length than corresponding finished only fabrics. The reduction in bending length is better in warp direction in Lipolase treated and finished fabrics and it is weft direction in Savinase treated ones. The maximum reduction is observed in enzyme treated and nano polysiloxane based (E1/E2) combination finished fabrics, since nano polysiloxane improves inner softness of textile materials.

Dry crease recovery angle: The Dry Crease Recovery Angle (DCRA) of finished and unfinished wool/cotton union fabric with and without prior enzyme treatments is given in Table 8. The ability of wool fiber to recover from unwanted wrinkle is superior to that of most other fibers including untreated cotton fiber and so the DCRA of this untreated fabric in weft direction is better than warp direction (Leeder and Rippon, 1998).

The improvement of crease recovery after each enzyme treatment is higher in weft direction than warp direction. After finishing, these two enzyme treated fabrics are showed uniform improvement in DCRA in warp direction (9.0 and 9.4%); while in weft direction the Lipolase treated and finished fabrics (19.1%) are showed better recovery than Savinase treated ones (14.7%) when compared to corresponding unfinished fabrics. It is inferred that these two enzyme treatment had lesser effect on DCRA in warp direction than weft direction.

Table 8: Dry crease recovery angle (°) of finished and unfinished wool/cotton union fabric with and without prior enzyme treatment

	Enzyme treatment					
	Warp			Weft		
Finishing formulation	UT	SAV	LIP	UT	SAV	LIP
EO	105	110	110	124	132	138
E1	108	111	114	137	143	152
E2	116	120	121	131	138	146
E3	111	116	115	142	151	154
E4	109	113	115	129	136	144
E5	109	114	113	136	146	148
E6	112	117	116	140	150	152

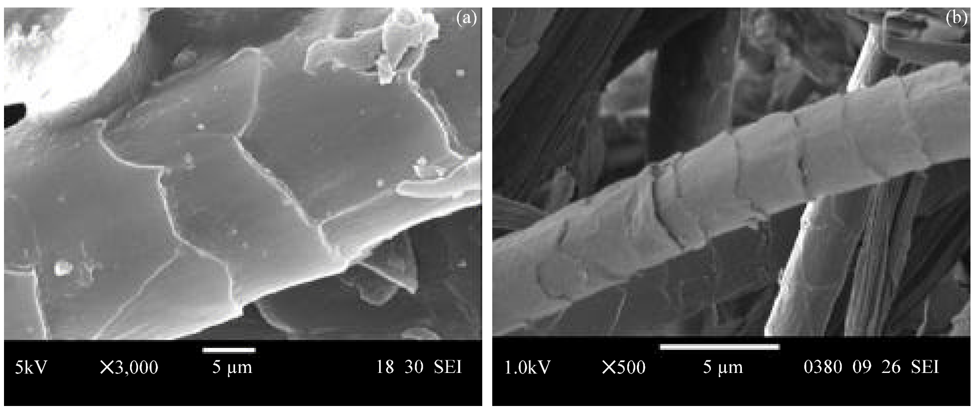

Fig. 5: (a) SEM photograph of Lipolase-100T treated and (b) lipolase treated and E4 combination finished wool fiber

SEM study: The SEM photographs of Lipolase 100T treated Fig. 5a and E4 combination finished Fig. 5b wool fiber are given in Fig. 5. From Fig. 5a, it is observed that SEM could detect no sign of fiber-surface modification since lipase did not penetrate significantly into the interior of the wool fiber and it will absorb strongly on the surface lipids on the wool cuticle. The removal of lipid layer presents on the epicuticle of wool fiber which acts as a major adsorption barrier for polymer particles leads to enhanced spreading and adhesion of polymer particles (Pille *et al.*, 1998; Nolte *et al.*, 1996). The formation of uniform thin film by E4 combination finish on the surface of lipolase modified wool fiber evidenced in Fig. 5b and it persuades the improvement of handle of finished fabric.

CONCLUSION

Based on the results of this work, the following conclusions could be drawn:

- Proteolytic enzyme treatment leads to improvement of acid groups on the wool surface, which enhances the hydrophilicity of wool fiber and also spreading and adhesion of finishing chemicals
- Lipolytic enzyme treatment causes removal of hydrophobic barrier on the wool surface, which results in chemical homogeneity of the scale surface and also increases surface free energy of wool fiber. This providing the driving force for the spreading and adhesion of finishing chemicals

- Proteolytic/lipolytic enzyme treatment causes also improvement of hydrophilicity of cotton portion on this union fabric which further enhances spreading of finishing chemicals
- The application of prior proteolytic/Lipolytic enzyme treatment on wool/cotton union fabric and subsequent treatment with different combination finishing formulations imparts broad range of soft handle with desired functional requirements such as hydrophlicity, durability etc. the degree of handle depends on the nature of finishing combinations applied
- The total hand value of enzyme treated and combination finished union fabric (3.3) falls on below high-quality winter suiting fabric, which may be due to thickness of the fabric
- The combined application of micro polysiloxane and a cationic softener with or without nano/macro polysiloxane could provide a soft silky hand. The S-SPG+C-MW+C-UP+S-SE1 combination finish on Savinase treated wool/cotton union fabric imparts better hand value than corresponding Lipolase treated ones and finished only fabrics

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