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Study on physical and handle properties of wool/ cotton union fabric treated with enzymes and different pre-polymer finishing chemicals

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Abstract

Wool/cotton union fabric was treated with a cellulase enzyme and a protease enzyme in separate and successive from followed by finishing with different pre-polymer finishing chemicals and their physical and handle properties were evaluated. The moisture related properties had been improved after each enzyme treatments and were modified after finishing, which depends on the nature of finishing chemicals applied. The tear strength of the fabric was reduced after enzyme treatments and it retained its original value in subsequent finishing treatments. The area shrinkage, drape coefficient and bending length of fabric were decreased after enzyme treatments and were further decreased in subsequent finishing treatments when compared to untreated fabric. The dry crease recovery angle and subjective handle were increased after enzyme treatments and was further increased significantly in finishing treatments. This study reveals that enzyme treatment followed by finishing with Sandosoft-SPG or Ceraperm-CW or their combination show better performance properties than other finished fabrics.

Keywords

Cotton; Enzyme; Finishing; Handle; Wool.

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INTRODUCTION

Indian wool has fineness of 30 to 60 micron with 5 to 50 % medullation so they mainly used (90-95%) for production of home textiles and technical textiles such as carpet, blanket, felt etc., and about 5-10% used for apparel manufacturing[1]. To meet out the wool requirements for apparel production, Central Sheep and Wool Research Institute (CSWRI), India had developed a fine wool crossbred named Bharat merino. The physical and chemical properties of that wool resemble fine wool (22.5±0.3μ, less than 1% medullation) except in fiber length, which is 40-60mm[2]. The production of fine yarn in the worsted system of spinning from this wool was limited due to its short fibre length. In order to explore this wool commercially, 4Nm woolen yarn was spun this wool in a single condensed carding system. It was woven in a handloom with cotton yarn as warp and this yarn as weft in twill weave form. The properties of that wool/cotton union fabric were evaluated and it satisfied the basic requirement for a shawl[3].

The concept of treating textiles with enzymes to improve surface properties was first developed in 1989. Enzyme treatments have bright prospects in textile processing as pretreatment and soft finishing[4-6]. They make

chemical treatments possible without the chemically and economically questionable alkaline pollution with cotton and the chlorinating process with wool[7-9]. Chikkodi et.al 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[10]. Enzyme treatment could also be improved the effectiveness of subsequent finishing treatment regardless of its structural characteristics. Many studies revealed that chemical finishes cause significant changes in performance properties of a fabric such as softness of cotton[11], wool[12] and wool/cotton[13] blended fabrics. The literature review reveals a void in research on the effect of cellulase enzyme and protease enzyme on wool/cotton union fabric. In this work the effects of cellulase/protease enzyme treatment in separate and successive forms on wool/cotton union fabric followed by finishing with different finishing chemicals has been assessed in terms of physical and handle properties.

MATERIAL AND METHODS

Materials

The wool/cotton union fabric with the following specification (TABLE 1) was procured from Southern Regional Research Station of CSWRI, Kodaikanal, Tamilnadu, India. Clariant Chemicals (India) Ltd. Mumbai, India supplied Bactosol-CA (an acid stable cellulase enzyme), Bactosol-WO (an alkaline protease enzyme), Sandoclean-PCJ (non-ionic wetting agent), Sandosoft-SPG (cationic softener), Ceraperm-MW (hydrophilic micro silicone emulsion), Finish-VLF (modified N-methylol dihydroxylethylene urea), Sandolube-HD (cationic softener), N-HPU (cationic fluorocarbon dispersion), Cerol-EWL (extender for fluorocarbon) and Ceraperm Aqua (modified polysiloxanes). Indian Sea Foods, Cochin, India supplied 81% deacetylated Chitosan. All other chemicals used in the study were AR grade.

TABLE 1 : Specification of wool/cotton union fabric

1	Ends per inch	40
2	Picks per inch	30
3	Weave	2/2 twill
4	Weight (g/m^2)	350
5	Warp count	2/15 Tex cotton yarn
6	Weft count	4 Nm woolen yarn

Methods

Enzyme treatments

Previous trails were undertaken by varying the concentration of enzymes based on ratio of wool and cotton in the fabric and enzyme' technical information. From the results, the standardized concentration for Bactosol-CA and Bactosol-WO was 1% (owf-over the weight of fabric) and 4% (owf) respectively. Bactosol-CA was applied using the following condition: 1% (owf) enzyme, MLR 1:10, pH of 5.0 (adjusted with 0.5%mll^{-1} acetic acid) at 50°C for 60 minutes. Bactosol-WO was applied using the following condition: 4% (owf) enzyme, MLR 1:10 and pH 8.5(adjusted with 0.5gl^{-1} sodium carbonate) at 55°C for 60 minutes. After each enzyme treatments the fabric was washed, rinsed well, dried at ambient condition.

Finishing treatments

Along with finishing chemicals (as per TABLE 2) 0.5gl^{-1} Sandoclean PCJ was added and the pH was adjusted to 5.0 with 0.5mll^{-1} acetic acid solutions. Fabric of 35 cm x 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 curing in high temperature steamer (R.B.Engineering Ltd., Gujarat, India) as per conditions mentioned in TABLE 2.

TABLE 2 : Recipe and conditions for finishing chemical treatments

Sr. No	Recipe	Curing condition	Abbreviation
1	Nuva-HPU – 60gl^{-1} Curol-CWI – 20 mll^{-1} Finish-VLF – 60gl^{-1}	160°C / 3 minutes	A1
2	Ceraperm-CW – 10 gl^{-1} Sandolube-HD – 30 mll^{-1} $MgCl_2$ – 12 gl^{-1}	150°C / 3 minutes	A2
3	Ceraperm-MW – 30 gl^{-1}	150°C / 3 minutes	A3
4	Sandosoft-SPG – 30 gl^{-1}	No curing	A4
5	Ceraperm-MW – 20 gl^{-1} Sandosoft-SPG – 40 gl^{-1}	150°C / 3 minutes	A5
6	Ceraperm-Aqua – 30 gl^{-1}	150°C / 3 minutes	A6
7	Chitosan – 1 gl^{-1}	130°C / 5 minutes	A7

A0 – unfinished fabric; the abbreviation are used in the following figures and tables

Chitosan application

Chitosan solution was freshly prepared by dissolving 1gm chitosan in 1litre of acetic acid solution (5% w/v) with constant stirring. Fabric of 35 cm x 35 cm dimension was impregnated in this solution for 2 minutes and padded with 80% expression. Then it was dried at

100°C and cured at 130°C for five minutes, rinsed with distilled water, neutralized and dried[14].

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 hours) and the following performance properties were evaluated as per established standard: moisture regain (ASTM D 1576:90-1995)[15], wettability (BS 4554:1970)[16], wicking height[17], drape coefficient (BS 5058:11973)[18], area shrinkage (BS EN ISO 6330:2001)[19], subjective assessment (in % handle)[20], bending length (BS 3356:1990)[21] and dry crease recovery angle (AATCC 66-2003)[22].

RESULTS AND DISCUSSION

A wool/cotton union fabric was treated with a cellulase enzyme and a protease enzyme in separate as well as successive form followed by finishing with different finishing chemicals. Then physical and handle properties of finished and unfinished fabrics with and without prior enzyme treatments had been evaluated and discussed below.

Finish add-on

The finish added in wool/cotton union fabric with and without prior enzyme treatments is given in TABLE 3. It depicts that finish add-on is higher in enzyme treated fabrics than non-treated. The highest add-on is observed in F-VLF finished fabrics (6.5%) and the lowest is found in C-Aqua finished fabrics (1.3%). Generally finish add-on depends on the presence of accessibility regions and functional groups in the fiber. The enzymatic treatment improves the wettability and also increasing the critical surface energy of fiber, which enhance the uniform spreading and adhesion of the polymer on the fiber surface[23,24].

TABLE 3 : Finish add-on (%) in finished and unfinished wool/ cotton union fabric with and without prior enzyme treatments

Sr. No	Treatment ⇒ / Finishing ⇓	Unttt	CE	PE	CE/PE
1	A0	0	-1.86*	-3.62*	-5.72*
2	A1	2.57	3.14	3.35	3.77
3	A2	3.78	5.22	5.73	6.49
4	A3	1.78	2.24	3.04	3.54
5	A4	1.02	1.32	2.63	2.91
6	A5	1.32	1.94	2.93	3.56
7	A6	0.68	0.70	1.13	1.34
8	A7	2.75	3.76	4.12	4.36

*** - Indicates the weight loss**
Unttt-Untreated
CE – cellulase enzyme treatment only
PE – protease enzyme treatment only
CE/PE – cellulase enzyme treatment followed by protease enzyme treatment

Moisture regain

The moisture regain of finished and unfinished wool/ cotton union fabric with and without prior enzyme treatments is given in Figure 1. It depicts that there is an improvement in moisture regain after each enzyme treatments. Bactosol-CA is a multi-component cellulolytic complex of cellobiohydrolase, endo-gluconase and beta-glucosidase. It acts on beta-1-4-glucoside linkages and depolymerize the cellulose molecule along with formation of more functional groups[25-27]. The protease enzyme specifically acts on the peptide bonds of wool molecule and creates more amino and carboxylic acid groups[28]. The removal of the proteinacious matter also causes removal of covalently bond fatty acids and this consequently enhances the hydrophilicity of the wool fiber[29,30]. The newly formed functional groups present in both wool and cotton fibres are responsible for improvement in moisture regain. While after finishing, it is decreased from 2% to 18%, when compared to untreated fabric and C-Aqua treated fabric (10.75%) retains more moisture than other finished fabrics.

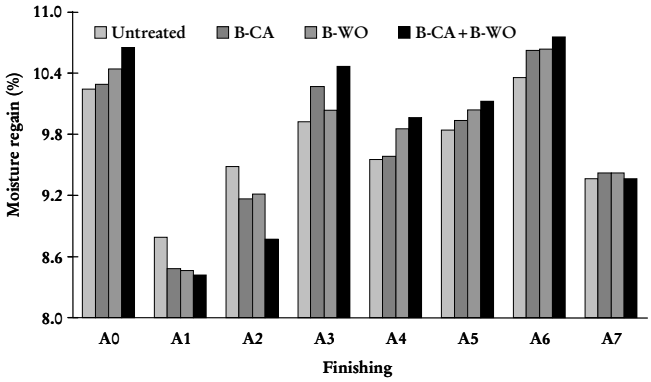


Figure 1 : Moisture regain (%)of finished and unfinished wool/ cotton union fabric with and without prior enzyme treatments

Wettability

The wetting time of finished and unfinished wool/ cotton union fabric with and without enzyme treatments is given in TABLE 4. It depicts that enzyme treatments improve the wettability of fabrics (10sec) when compared to untreated fabric (104 sec). After finishing, the wetting time is varied and is depended on the functional groups present in the polymer film/ network formed on the fiber. It is lowest in enzyme treated and C-MW finished fabric (10 sec) and no wettability is found in N-HPU finished fabric (>360sec).

TABLE 4 : Wettability (sec) of finished and unfinished wool/ cotton union fabric with and without prior enzyme treatments

Sr. No	Treatment ⇒ / Finishing ⇓	Unttt	CE	PE	CE/PE
1	A0	104	10	12	9
2	A1	> 360	> 360	> 360	> 360
3	A2	98	24	38	30
4	A3	78	17	18	10
5	A4	139	127	105	105
6	A5	127	123	89	98
7	A6	45	29	25	18
8	A7	102	89	93	97

Wicking behavior

The mean wicking height of warp and weft direction in finished and unfinished wool/cotton union fabric with and without prior enzyme treatments is given in TABLE 5. It depicts that mean wicking height is improved after each enzyme treatments. Wetting and wicking are two related properties; a liquid that does not wet fiber cannot wick into a fabric, so fiber wettability is a prerequisite of wicking[31]. In enzyme treated and finished fabrics it depends on the nature of the finishing chemical applied that is it is highest in C-Aqua finished fabric (95 mm) and lowest in N-HPU finished fabric (0 mm). Fluorocarbon chemical form a thin hydrocarbon film on the surface of the fiber[32] and other finishing chemical blocking the hydrogen bonding groups in fiber polymer such as –OH, -NH_2, -COOH, etc., which are responsible for lowering the wicking height[33].

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

Sr. No	Treatment ⇒ / Finishing ⇓	Unttt	CE	PE	CE/PE
1	A0	15.0	74.0	76.0	85.5
2	A1	0.0*	0.0*	0.0*	0.0*
3	A2	26.0	75.5	52.0	57.5
4	A3	27.5	52.5	58.0	68.0
5	A4	11.5	31.0	26.0	15.5
6	A5	12.5	21.0	27.0	31.0
7	A6	31.5	67.0	91.5	95.0
8	A7	5.5	7.5	16.0	11.0

*- Indicates no wicking

Tearing strength

The retention of tearing strength of finished and unfinished wool/cotton union fabric with and without prior enzyme treatments is given in Figure 2. It infers that each enzyme treatments reduced the tearing strength while subsequent finishing treatment retains the original value and then improves to the extent of 108%. The highest retention is found in chitosan-finished fabric and lowest in S-SPG finished fabric. The improvement in strength is due to de-convolution of cotton fiber as well as swelling of wool fiber through the deposition of polymerizing resins within the interior of wet swollen fibers and the subsequent formation of longer and flexible cross links of cellulose/ polyamide polymer through their functional groups[34,35].

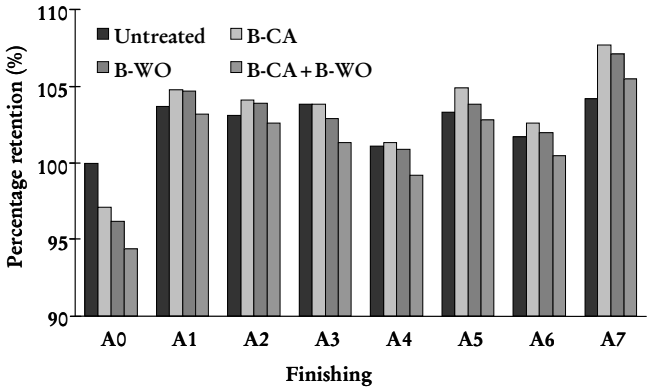


Figure 2 : Retention of tearing strength (%) of finished and unfinished wool/cotton union fabric with and without prior enzyme treatments

Area shrinkage

The area shrinkage of finished and unfinished wool/ cotton union fabric with and without prior enzyme treatments is given in Figure 3. The area shrinkage of untreated fabric is 7.0 %, which is lower than 100 % finished wool suiting fabric from CSIRO (8.1%)[36]. The area shrinkage in protease enzyme treated fabrics[37,38] are lower (< 4%) than only cellulase enzyme treated fabric (4-6%) since only wool would be felting during washing[39]. The enzyme treated and finished fabrics are shrunk lesser than finished-only fabrics and the extent of which depends on the nature of finishing chemical applied; the lowest is observed in enzyme

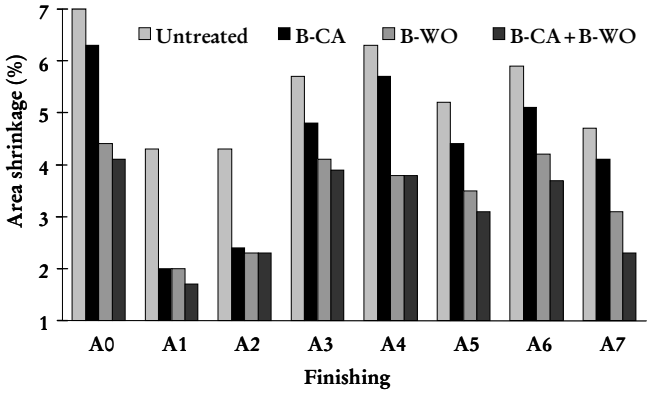


Figure 3 : Area shrinkage (%) of finished and unfinished wool/ cotton union fabric with and without prior enzyme treatments

treated and N-HPU finished fabric[40] (1.7%) and highest in Sandosoft-SPG finished fabric (5.7%).

Drape coefficient

The drape coefficient of finished and unfinished wool/cotton union fabric with and without prior enzyme treatments is given in Figure 4. A drape coefficient between 25% and 50% would indicate a drapeable fabric and those with greater than 75% are stiffer and less drapeable[41]. It also depends on mechanical properties, finishing conditions and fabric history[42]. This fabric could be considered as drapeable fabric since it has drape coefficient of 54.2%. Enzyme treated fabrics show improvement in drapeability while after finishing, the chitosan finished fabric decreases its drapeability and combined S-SPG and C-MW finished fabric improves drapeability, when compared to control fabric.

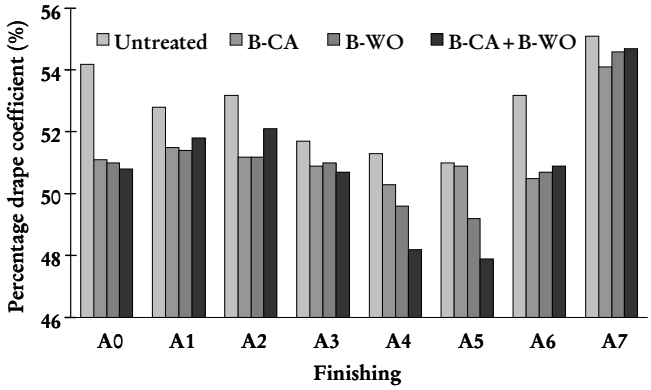


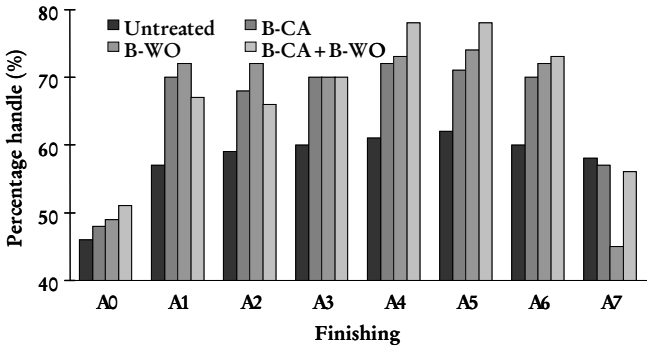
Figure 4 : Drape coefficient (%) of finished and unfinished wool/cotton union fabric with and without prior enzyme treatments

Subjective assessment

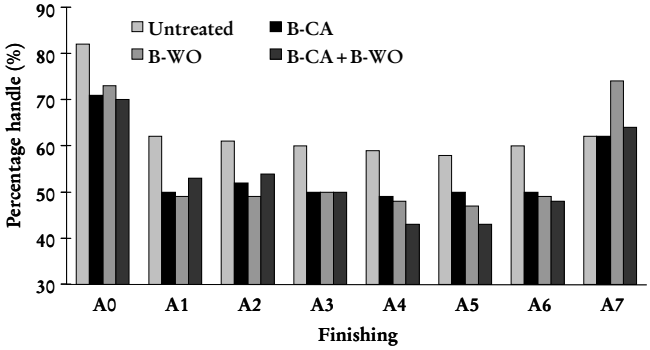
The handle of finished and unfinished wool/cotton union fabric with and without prior enzyme treatments in terms of softness and roughness is given in Figure 5 as 5a and 5b respectively. All judges prefer enzyme treated and combined S-SPG and C-MW finished fabrics in terms of smoothness and softness. Hydrophilic siloxanes have a much higher hydrophilic effect and this has very positive effect on the wearing comfort of the finished fabric[43]; the cationic softener reduces fabrics friction[44], modifies fabric handle and feel and so their combination reaches the desired effect[45]. The finished-only fabrics reduce the stiffness and roughness between 43% and 27% respectively with moderate improvement in softness (12-20%) and smoothness (14-23%).

Bending length

The bending length of finished and unfinished wool/cotton union fabric in warp and weft direction with and without prior enzyme treatments is given in TABLE 6. It depicts that bending length of control fabric is higher in weft direction than warp direction, which is due to variation in linear density of yarn. This trend is also observed in enzyme treated and finished fabrics. The bending length is reduced 3% in single



(5a) : Softness



(5b) : Roughness

Figure 5 : Handle (%) of finished and unfinished wool/cotton union fabric with and without prior enzyme treatments

TABLE 6 : Bending length (mm) of finished and unfinished wool/cotton union fabric with and without prior enzyme treatments

Direction	Sr. No	Finishing ⇓	Treatment ⇓			
			Unttt	CE	PE	CE/PE
Warp	1	A0	14.5	14.2	13.6	13.4
	2	A1	13.6	12.5	13.5	13.9
	3	A2	12.8	11.6	12.7	12.7
	4	A3	12.6	11.7	12.5	12.3
	5	A4	12.4	12.1	12.0	12.0
	6	A5	12.2	11.9	12.1	11.5
	7	A6	12.6	12.4	12.5	12.0
	8	A7	13.3	13.1	13.1	13.0
Weft	1	A0	15.6	15.0	14.9	14.8
	2	A1	15.6	14.6	14.8	15.2
	3	A2	15.0	14.2	14.3	15.1
	4	A3	15.2	14.3	14.5	14.2
	5	A4	14.1	13.7	13.0	13.8
	6	A5	14.3	13.9	13.6	13.7
	7	A6	15.0	14.4	14.3	14.0
	8	A7	15.0	14.3	14.3	14.1

enzyme treatment and 6% in successive enzyme treatments than control fabric in warp and weft direction respectively. The lowest reduction in bending length is 3% in enzyme treated and N-HPU finished fabric and highest is 20% in S-SPG finished fabric. The chitosan-finished fabric shown higher stiffness than other finished fabrics, which is due to formation of stiff molecular chain of chitosan[46] when compared to control fabric.

Dry crease recovery angle (DCRA)

The sum of dry crease recovery angle in warp and weft direction of finished and unfinished wool/cotton union fabric with and without prior enzyme treatments is given in Figure 6. It infers that total DCRA of unfinished fabric is slightly increased in warp direction (1.1%) after cellulase enzyme treatment, in weft direction (2.8%) after protease enzyme treatment and in both directions (5.6%) after successive enzyme treatments. The total DCRA of enzyme treated and finished fabrics is lower in chitosan-finished (192°) fabric and higher in S-SPG + C-MW finished (214°) fabric than other finished fabrics.

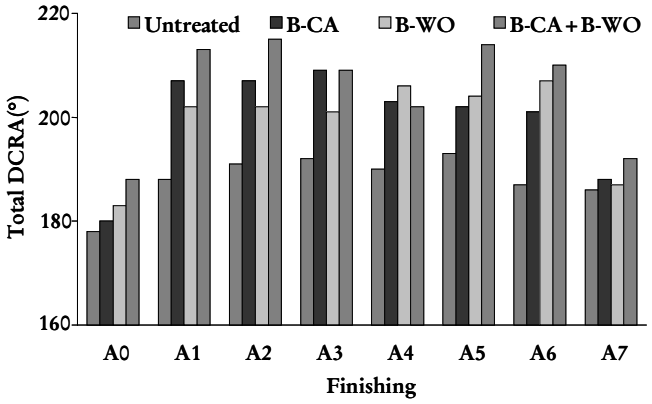


Figure 6 : Total dry crease recovery angle (°) of finished and unfinished wool/cotton union fabric with and without prior enzyme treatments

CONCLUSION

Prior cellulase/protease enzyme treatments on wool/cotton fabric improve the critical surface energy of its constituent fibers and enhance the adhesion and spreading of finishing chemical irrespective of their structural characteristics. So the finish add-on is higher in enzyme treated than untreated fabric. The moisture related properties are significantly improved after enzyme treatments and are modified in subsequent finishing treatments, which depend on the nature of the finishing chemicals applied. The tear strength is reduced after enzyme treatments and retained its original value in subsequent finishing treatments. The subjective assessment reveals that enzyme treatments reduce the stiffness and roughness of fabric without change in softness and smoothness, while the subsequent finishing treatments provide good softness and smoothness feel with further reduction in stiffness and roughness. All judges prefer enzyme treated and combined S-SPG and C-MW finished fabrics for better handle and softness. The bending length and drape coefficient of fabrics are decreased after enzyme treatments and are further decreased in subsequent finishing treatments and it is higher in enzyme treated and S-SPG + C-MW finished fabric than other finished fabrics. The dry crease recovery angle both in warp and weft directions are improved after enzyme treatments as well as in subsequent finishing treatments. The properties of enzyme treated and finished fabrics are comparatively superior to finished-only fabrics and enzyme treated fabrics. It is concluded that the physical and handle properties of the wool/cotton union fabric could be improved by successive treatment with cellulase and protease enzyme followed by finishing with S-SPG or C-CW or their combination.

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