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Study on Modification of Physical Properties of *Khadi* Fabrics by Enzymatic Treatment

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ABSTRACT Enzymes are present in living organisms but are not living themselves. Enzymes are very mild components in the environment. Enzymes acts as a molecular worker offering an answer to the desire for a cleaner more gentle less polluting, non-aggressive and hyper genic chemistry with minimum damage to textile substrate and the environment. Present investigation was aimed to assess the effect of enzymatic agents on physical properties of *khadi* fabrics. Cotton *khadi* and cotton blend *khadi* fabrics have been selected for this study. Physical properties of treated fabrics were analyzed statistically. Enzymatic treatment was given at different concentrations. The treated *khadi* fabrics were evaluated in terms of fabric weight loss, stiffness, tensile strength, tearing strength, crease recovery and drapability. It was found that as the concentration of enzymes increased, drapability and number of nodes of treated fabrics were also increased. Cellulase treated fabrics were graded as the best (highest THV), followed closely by amylase treated fabrics.

INTRODUCTION

"Khadi" means any cloth that is handspun and hand woven, made of cotton, wool, silk and their blends. Hand spinning and weaving imparts it a rugged texture, a unique look, feel and hand, which can be modified by finishing treatment.

Finishing, the final step of chemical processing, is carried out to improve the properties, aesthetic appeal and serviceability of textile materials. The treatment of textiles with substances that modify their surface properties has been a common practice since most ancient times. Stiffening and softening of textiles becomes an important finishing process of many after treatment processes in a textile chemical processing industry.

Stiffness, an attribute of fabric hand, is one of the most important factors determining draping quality. According to Peirce, stiffness is the key factor in the study of drape and hand. Quantitatively the stiffness of fabric is measured in terms of the bending length and flexural rigidity.

Enzymes can be used to make the fabric handle soft. A study conducted by Patel (1994) revealed that cellulase effectively improves cotton surface appearance, hand and drape.

Enzymes have reached enormous industrial importance over the past decade. Toxic and environmentally benign, these biocatalysts are capable of improving hand and appearance properties of cellulosic goods at very low concentration. In an experimental work pure cotton and cotton polyester blend were treated with cellulase, and consequently considerable improvement in softness was observed (Diller et al. 1999).

Riyao (1999) found that cellulase enzyme reduced pilling tendency, modified fabric softness, drapability and transformed low quality fabric into high quality textiles in an environment friendly manner.

Das (2010) observed that cotton fabrics processed with enzymes registered better hand feeling than traditional method. Significant saving of water due to lower liquor ratio in desizing and scouring method of enzymatic processes exert less effluent load an environment. However economics do favor traditional methods. But considering better durability, fastness, feel of the fabric and environment friendly processing, enzymatic process may be preferred.

It is on the basis of the above context that the present work was planned. Cotton *khadi* and its blends were treated with different enzymes namely, amylase and cellulase to modify stiffness and drape. Effect of enzymes on wrinkle recovery, strength and hand were also studied.

Objectives

To study the effect of selected enzymes on the properties of *khadi* fabrics that is, stiffness, drape, wrinkle recovery, tearing strength and smoothness.

MATERIAL AND METHODS

Fabric

Commercially available *khadi* fabrics with different weight and thickness were used. Three categories of cotton *khadi* fabrics were selected for this study, that is, light, medium and heavy weight and two types of poly *khadi* that is, light and heavy weight were used. Table 1 presents the different codes given to the fabrics used in this study.

Table 1: Codes given to the fabrics used in the study

Name of the fabrics	*Weight*	*Fabric codes*
Cotton *khadi*	Light weight	CL
Cotton *khadi*	Medium weight	CM
Cotton *khadi*	Heavy weight	CH
Cotton polyester blend *khadi*	Light weight	CPL
Cotton polyester blend *khadi*	Heavy weight	CPH

Enzymes

Commercially available amylase and cellulase enzymes were selected for treatment of cotton *khadi* and poly *khadi* fabrics. Preliminary data of different finishes has been given in Table 2.

Table 2: Preliminary data of finishes used

S. No.	*Name of finish*	*Commercial trade names*
1.	Amylase Enzyme	Resil Enzymatic preparation- EZYSIZE FLEX CONC. UTRA 196
2.	Cellulase	HYBRID

Preliminary data of fabrics that is, thread count, thickness and weight and unit area were determined by standard procedures.

METHODOLOGY

Application of Amylase Enzyme

Fabric was passed through hot water and padded with desizing mixture containing 0.5 percent to 1 percent enzymes and nonionic detergents. Fabric was treated at 60^0 C to 70^0C at pH 6.5-7.5 for 2 hours (pH is maintained by acid and alkali) (Schindler and Hausen 2004).

Application of Cellulase Enzyme

Fabric was treated with 0.5 percent to 1 percent cellulase enzyme at 4.5-5.5 pH for 45 to 60 minutes. Temperature was maintained at 45^0 C to 60^0 C (Karmarker 1999).

Determination of Percent Weight Loss of the Finish

Weight of fabric before treatment and after treatment was taken. Percent weight loss of finished product was calculated using formula:

Percent weight loss of fabric = $W_1 - W_2/W_1{}^* 100$

W_1 = Weight of fabric before treatment

W_2 = Weight of fabric after treatment

The following selected properties were measured as per standard test methods

- Stiffness (IS: 6490-1971)
- Percent Drape Coefficient (IS: 8357-1977)
- Crease recovery (IS: 4681-1968)
- Flexural Rigidity (IS: 6490-1971)
- Tearing Strength (IS: 6484-1971)
- Hand (KES).

Statistical Analysis

Mean, standard deviation, ANOVA and correlation coefficients were used for statistical analysis of data.

RESULT AND DISCUSSION

Effect of Amylase on Stiffness

Table 3 shows bending length of cotton *khadi* and poly *khadi* fabrics treated with varying concentration of amylase enzyme. It is clear that there is weight loss in amylase enzyme treated fabric.

It is observed from the table that stiffness of *khadi* fabrics has decreased after treating with amylase enzyme. But extent of decrease is different in different fabrics. Marked decrease in stiffness in heavy weight poly *khadi* fabric is found whereas decrease in stiffness of other cotton and poly *khadi* fabrics is not very pronounced.

Table 3: Stiffness of *khadi* fabrics treated with varying concentration of Amylase

Fabric name and its codes	Conc. of finish (W/W)	% weight loss	Bending length (cm)				Warp and weft Average
			Warp		Weft		
			M	SD	M	SD	
Cotton Khadi CL	Control	0	2.8	0.2	2.0	0.3	**2.4**
	0.5%	4.1	2.6	0.1	2.0	0.2	**2.3**
	1%	1.5	2.5	0.3	2.1	0.1	**2.3**
	1.5%	1.9	2.4	0.2	2.0	0.3	**2.2**
CM	Control	0	2.2	0.3	1.9	0.3	**2.0**
	0.5%	3.2	2.0	0.1	1.7	0.1	**1.9**
	1%	8.1	2.0	0.1	1.8	0.2	**1.9**
	1.5%	10.5	2.1	0.3	2.3	0.3	**2.2**
CH	Control	0	2.5	0.3	2.5	0.3	**2.5**
	0.5%	1.2	2.2	0.2	2.2	0.3	**2.2**
	1%	0.9	2.4	0.1	2.3	0.2	**2.3**
	1.5%	0.6	2.5	0.5	2.4	0.1	**2.4**
Poly Khadi CPL	Control	0	2.9	0.3	2.6	0.2	**2.7**
	0.5%	11.6	2.5	0.1	2.0	0.1	**2.2**
	1%	3.2	2.8	0.1	2.3	0.1	**2.6**
	1.5%	2.5	2.7	0.2	2.2	0.2	**2.4**
CPH	Control	0	4.8	0.1	3.3	0.2	**4.0**
	0.5%	2.7	3.1	0.2	2.4	0.1	**2.7**
	1%	2.0	2.9	0.1	2.2	0.2	**2.6**
	1.5%	1.9	2.7	0.2	2.5	0.2	**2.6**

No particular trend is seen with regard to effect of concentration of enzyme. According to Saravanan et al. (2010), all the response curves of cellulose characterization show initially an increasing tendency followed by a decrease after reaching a peak, adhering to the characteristic curve of the enzyme activity. This indicates that enzymes are active up to certain level (conc.) after that their effectiveness decreases or becomes constant.

According to Gulrajani (1998), enzyme treatment improves the various properties of fabrics. Surface smoothness is increased and consequently the bending rigidity and shear rigidity of the treated fabric. Thus, enzyme treatment leads to overall value addition to the handle and feel of the cotton knitted fabric.

This is due to partial hydrolysis of fibers with cellulase enzyme. Enzymes attack cellulose molecular chains and cause their breakdown. This results in reduction in crystallinity of fiber polymer system thus enhancing softness of fabric.

Three way ANOVA is applied to find out the effect of amylase finish concentration, fabric types and warp and weft direction on stiffness. Effect of fabric types on stiffness is significant at one percent level (F=18.76). Effect of warp and weft direction on stiffness is significant at one percent level (F=25.96) and effect of concentration on stiffness is found significant at one percent level (F=2304.58). Interaction between fabric types and warp and weft direction is significant (F=3.20). Interaction between concentration of finishes and warp and weft direction is significant (F=3788.43) and interaction between fabric, concentration of finish and warp weft direction is also found significant (F=570.40). Thus, all three factors significantly (F=973.34) affected the stiffness of cotton *khadi* and poly *khadi* fabrics.

Effect of Cellulase on Stiffness

Comparative analysis of stiffness of cotton *khadi* and poly *khadi* fabrics with varying thickness in Table 4 shows that stiffness of CL has increased a little after treating with cellulase enzyme. On the other hand, stiffness of CM decreases very slightly at 0.5 percent concentration and then increases at one percent concentration. In case of CH, stiffness decreases continuously with increase in concentration of cellulase enzyme. Similar trend is found with CPL, whereas stiffness of CHL decreases considerably at 0.5 percent and after that it increases and

Table 4: Stiffness of khadi fabrics treated with varying concentration of Cellulase

Fabric name and its codes	*Conc. of finish (W/W)*	*% weight loss*	*Bending length (cm)*				*Warp and weft average*
			Warp		*Weft*		
			M	*SD*	*M*	*SD*	
Cotton Khadi CL	Control	0	2.8	0.2	2.0	0.3	**2.4**
	0.5%	0.5	2.8	0.2	2.2	0.0	**2.5**
	1%	0.5	2.7	0.1	2.3	0.1	**2.5**
CM	Control	0	2.2	0.3	1.9	0.3	**2.0**
	0.5%	1.9	1.9	0.1	1.9	0.9	**1.9**
	1%	1.6	2.2	0.1	2.2	0.1	**2.2**
CH	Control	0	2.5	0.3	2.5	0.3	**2.5**
	0.5%	0.3	2.4	0.2	2.3	0.2	**2.4**
	1%	0.3	2.2	0.2	2.5	0.1	**2.3**
Poly Khadi CPL	Control	0	2.9	0.3	2.6	0.2	**2.7**
	0.5%	1.5	2.8	0.1	2.5	0.9	**2.6**
	1%	6.3	2.2	0.2	2.3	0.1	**2.2**
CPH	Control	0	4.8	0.1	3.3	0.2	**4.0**
	0.5%	0.1	3.4	0.2	3.4	0.2	**3.4**
	1%	1.7	4.6	0.2	3.3	0.2	**4.0**

becomes similar to untreated fabric at one percent concentration. Thus it can be said that cellulase enzyme has improved textural property of *khadi* fabrics.

Three way ANOVA is applied to find out the effect of cellulase finish concentration, fabric types and warp and weft direction on stiffness. Effect of fabric types on stiffness is significant at one percent level (F= 4106.33). Effect of warp and weft direction on stiffness is significant at one percent level (F=18366.66) and effect of concentration on stiffness is found significant at one percent level (F=9282.33). Interaction between fabric types and warp and weft direction is significant (F=12682.83). Interaction between concentration of finishes and warp and weft direction is significant (F=27632.33) and interaction between fabric, concentration of finish is also found significant (F=6417). Interaction between fabric, concentration of finish and warp weft direction is also found significant (F=14974.66). Thus all three factors significantly affected the stiffness of cotton *khadi* and poly *khadi* fabrics.

Effect of Amylase on Flexural Rigidity of Fabrics

The flexural rigidity of finished cotton *khadi* fabric and poly *khadi* fabrics after amylase enzyme treatment is given in Table 5 and compared with unfinished fabrics.

It is evident that the bending rigidity of *khadi* fabric in warp and weft directions is significantly reduced after enzyme treatment in all finishing concentrations.

Major changes are noticed in poly cotton *khadi* fabrics of light weight as well as heavy fabrics. The heavy weight cotton *khadi* fabric shows noticeable decrease in bending rigidity as compared to heavy and lightweight cotton fabrics at 0.5 percent concentration. Increasing the concentration further has increased rigidity in almost all the fabrics.

Table 5: Flexural rigidity of *khadi* fabrics treated with varying concentration of Amylase

Name of fabric and its code	*Conc. of finish (W/W)*	*Flexural rigidity (mg/cm)*		
		Warp	*Weft*	*Warp and weft average*
Cotton Khadi CL	Control	170.4	70.8	**120.6**
	0.5%	138.0	62.1	**100.0**
	1%	131.7	81.5	**106.6**
	1.5%	110.0	68.8	**89.4**
CM	Control	138.6	89.2	**113.9**
	0.5%	110.5	74.6	**92.5**
	1%	107.2	86.4	**96.8**
	1.5%	136.7	175.4	**156.1**
CH	Control	238.8	238.8	**238.8**
	0.5%	169.5	162.7	**166.1**
	1%	214.0	206.1	**210.0**
	1.5%	241.7	211.3	**226.5**
Poly Khadi CPL	Control	171.9	123.9	**147.9**
	0.5%	114.1	61.6	**87.9**
	1%	131.7	81.5	**106.6**
	1.5%	141.8	81.3	**111.6**
CPH	Control	1214.6	394.7	**804.7**
	0%	327.2	153.7	**240.4**
	1%	293.6	128.4	**211.0**
	1.5%	218.6	188.6	**203.6**

Effect of Cellulase on Flexural Rigidity of Fabrics

Result of evaluation of bending rigidity of *khadi* cotton fabrics and poly *khadi* fabrics subjected to enzyme treatment has been presented in Table 6. This work demonstrates that improvement in tactile quality occurs after cellulase treatment of *khadi* fabrics in the following order:

Table 6: Flexural rigidity of *khadi* fabrics treated with varying concentration of Cellulase

Name of fabric and its code	Conc. of finish (W/W)	Flexural rigidity (mg/cm) Warp	Weft	Warp and weft average
Cotton Khadi CL	Control	170.4	70.8	**120.6**
	0.5%	183.5	82.6	**133.0**
	1%	152.8	94.4	**123.6**
CM	Control	138.6	89.2	**113.9**
	0.5%	92.1	99.5	**95.8**
	1%	144.3	138.6	**141.4**
CH	Control	238.8	238.8	**238.8**
	0.5%	233.2	200.9	**217.0**
	1%	181.2	238.8	**210.1**
Poly Khadi CPL	Control	171.9	123.9	**147.9**
	0.5%	154.7	76.1	**132.4**
	1%	110.1	89.1	**82.6**
CPH	Control	1214.6	394.7	**804.7**
	0.5%	427.7	427.7	**427.7**
	1%	757.0	409.2	**583.1**

Heavy weight poly khadi > lightweight poly khadi > heavy weight cotton

Rigidity of light weight cotton has slightly increased whereas no particular trend is found in medium weight *khadi*.

Effect of Amylase on Crease Recovery Angle of Fabric

The results of wrinkle recovery of treated fabric are shown in Table 7. It is observed that in general treatments with amylase, there is increased wrinkle recovery but no particular trend is observed that is, the increase in wrinkle recovery is not same in all cases.

On comparing wrinkle recovery of fabrics, it is observed that the medium weight cotton *khadi* fabric shows maximum increase in wrinkle recovery angle in warp direction as well as in weft direction over untreated fabrics. This is due to the accelerated catalytic reaction at high temperature of amylase enzyme treatment. After treatment with amylase enzyme fabric becomes soft and limp thus crease recovery angle is increased in treated fabrics.

It is also observed that increase in recovery in CL is at 0.5 percent concentration and after that it decreases. While in CH and CPH, increase in crease recovery angle is noted at one percent

Table 7: Crease recovery of *khadi* fabrics treated with varying concentration of Amylase

Fabric name and its codes	Conc. of finish (W/W)	% weight loss	Bending length (cm) Warp M	Warp SD	Weft M	Weft SD	Warp and weft average
Cotton Khadi CL	Control	0	56.0	8.2	85.0	5.0	**70.5**
	0.5%	4.1	80.0	5.0	77.0	7.5	**78.5**
	1%	1.5	67.0	8.3	71.0	6.5	**69.0**
	1.5%	1.9	72.0	7.5	72.0	4.4	**72.1**
CM	Control	0	88.8	7.3	96.8	4.8	**92.8**
	0.5%	3.2	100.0	7.9	92.0	7.5	**96.0**
	1%	8.1	92.0	7.5	97.0	11.5	**94.5**
	1.5%	10.5	97.0	2.7	97.4	7.1	**97.2**
CH	Control	0	74.0	4.1	76.0	12.9	**75.0**
	0.5%	1.2	77.1	8.4	62.0	18.9	**69.8**
	1%	0.9	93.0	13.5	76.0	8.2	**84.5**
	1.5%	0.6	79.0	18.5	65.0	13.2	**72.0**
Poly Khadi CPL	Control	0	101.0	6.5	86.0	9.6	**93.5**
	0.5%	11.0	91.1	5.5	92.2	7.5	**91.9**
	1%	3.2	88.0	16.8	85.0	6.1	**86.5**
	1.5%	2.5	90.0	10.0	86.0	8.2	**88.0**
CPH	Control	0	77.6	13.8	91.0	11.4	**84.3**
	0.5%	2.7	70.1	9.3	84.0	11.4	**77.0**
	1%	2.0	91.4	13.6	97.0	8.3	**94.2**
	1.5%	1.9	75.0	94.0	85.0	2.5	**80.0**

concentration. Moreover, in some fabrics increase is found in warp direction whereas in others it is in weft direction. This may be due to sampling fluctuation. *Khadi* fabrics have been used in this study made of handspun yarn of short staple fibers. Extent of variation and irregularity is quite high in these fabrics. That is why no particular trend is found.

ANOVA has been calculated to assess interaction between all variables and it is depicted that crease recovery angle of different fabrics is significantly (F=90.52) different from each other. Different concentrations of enzymes affect significantly affect crease recovery angle at one percent level (F= 4.89). Effect of warp and weft direction on wrinkle recovery is insignificant. Interaction between fabrics and warp and weft variables is found significant at one percent level (F=906.99). Interaction between concentration of finishes and warp and weft direction is significant at one percent level (F=9.68) and interaction between fabric, concentration of finish is again significant at one percent level (F=22.36). Thus all three factors fabric of warp weft direction of fabric, concentration and finishes are found significant at one percent level (F= 258.23) on the crease recovery of cotton *khadi* and poly *khadi* fabrics.

Effect of Cellulase Enzyme on Crease Recovery of Fabrics

The crease recovery angle of finished and unfinished cotton *khadi* and poly *khadi* fabric with and without enzyme treatments is given in Table 8. Average values show that little increase in crease recovery is found in cotton *khadi* fabrics whereas opposite trend is found in poly *khadi* fabrics. The improvement in crease recovery after enzyme treatment is higher in warp direction than in weft direction in CL, CM and CH. It is inferred that enzyme treatment has less effect on crease recovery angle.

ANOVA result shows that the effect of cellulase on crease recovery angle with different fabrics at different concentrations is significant that is, there is a significant difference between the crease recovery angle of different type of fabrics (F=154.1) of concentration of finish at five percent level (F=629.1) and direction of fabric (F=314.64) at one percent level. Interaction between the fabric and warp and weft direction is also found significant at one percent level (F=153.36). Interaction between concentration of finishes and warp and weft direction is significant at one percent level (F=943.17) and interaction between fabric, concentration of finish is again significant at one percent level (F=2365.05). Thus all three factors of fabric, warp weft direction of fabric, concentration of finish is found significant at one percent level (F=3398.36) on the crease recovery of cotton *khadi* and poly *khadi* fabrics.

Effect of Amylase on Drapability

It is clear from Table 9 that percent drape coefficient decreases after treating the cotton

Table 8: Crease recovery of *khadi* fabrics treated with varying concentration of Cellulase

Fabric name and its codes	*Conc. of finish (W/W)*	*% weight loss*	*Bending length (cm)*				*Warp and weft average*
			Warp		*Weft*		
			M	*SD*	*M*	*SD*	
Cotton Khadi	Control	0	56.0	8.2	85.0	5.00	**70.5**
CL	0.5%	0.5	71.0	4.1	76.0	6.5	**73.5**
	1%	0.5	65.0	3.5	80.0	15.8	**72.5**
CM	Control	0	88.8	7.3	96.8	4.8	**92.8**
	0.5%	1.9	100.0	6.1	87.0	5.7	**93.5**
	1%	1.6	97.0	13.0	94.0	4.1	**95.5**
CH	Control	0	74.0	4.1	76.0	12.9	**75.0**
	0.5%	0.3	79.0	8.9	79.0	10.8	**79.0**
	1%	0.3	74.0	10.8	79.0	4.1	**76.5**
Poly Khadi	Control	0	101.0	6.5	86.0	9.6	**93.5**
CPL	0.5%	1.5	97.0	5.7	87.0	4.4	**92.0**
	1%	6.3	86.0	4.4	91.0	4.1	**88.5**
CPH	Control	0	77.6	13.8	91.0	11.4	**84.3**
	0.5%	0.1	81.0	8.9	78.0	7.0	**79.5**
	1%	1.7	79.0	12.9	75.9	7.0	**77.0**

and poly *khadi* fabrics of all thicknesses with amylase.

Highest reduction in percent drape coefficient is found in light weight poly *khadi* fabric. Next level of decrease is in heavy weight cotton *khadi*.

Amylase has been applied on fabrics at three different concentrations that is, 0.5 percent, one percent and 1.5 percent. At 0.5 percent, percent drape coefficient decreased sharply. As the concentration of amylase is increased further, the drape coefficient increases very marginally. This trend is found in all the *khadi* fabrics used in the study.

When amylase is applied on fabrics, there is greater weight loss in fabrics. Due to greater weight loss fabrics becomes lighter and softer, which results in decrease in percent drape coefficient progressively. The correlation coefficient has been determined between fabrics drape coefficient and weight loss percentage. High positive correlation (r = 0.650) significant at 0.01 level has been found between these two properties.

Similar result has been given by other worker. The decrease in drape coefficient and the flexural rigidity lead to the improvement in the handle of the cotton knits after cellulase treatment (Karmakar 1999).

In case of amylase finish, the number of nodes increases and drape area is decreased in all thickness of cotton and poly *khadi* fabrics. Improved drapability is result of fabric softening that is, reduction in bending length on amylase application especially of low concentration. Positive correlation (r = 0.674) significant at 0.01 level is found between drape coefficient and stiffness.

One-way ANNOVA is applied to find out the effect of amylase enzyme concentration on drapability of different fabrics. Effect of concentration of amylase enzyme finish on drapability is found significant at the one percent level (F= 47736). Thus concentration of finish significantly affects the drapability.

Effect of Cellulase on Drapability

Data given in Table 10 shows effect of cellulase enzyme on percent drape coefficient of cotton *khadi* and poly cotton *khadi* blends is almost similar to that of amylase treated fabrics.

It is noted from the Table 4 that percent drape coefficient of fabric decreases markedly after treating with 0.5 percent cellulase. With increase in concentration of cellulase to one percent, drape coefficient remains static in light weight cotton *khadi*, light weight poly *khadi* and heavy weight poly *khadi*. Whereas in medium weight cotton *khadi* and heavy weight cotton *khadi*, it decreases slightly. This is explained again on the softness of fabrics. Due to decrease in stiffness of fabrics, sharp decrease in percent drape coefficient is noted.

Table 9: Drapeability of *khadi* fabrics treated with varying concentration of Amylase

Fabric name and its codes	*Concentration of finish(W/W)*	*% weight loss*	*% drape coefficient*		*No. of nodes*
			M	*SD*	
Cotton Khadi CL	Control	0	90.17	2.67	3.6
	0.5%	4.1	66.75	3.83	4.0
	1%	1.5	75.56	0.76	4.4
	1.5%	1.9	68.4	2.42	4.0
CM	Control	0	70.2	3.3	4.6
	0.5%	3.2	47.6	4.2	5.4
	1%	8.1	50.8	2.8	5.0
	1.5%	10.5	55.2	2.4	4.8
CH	Control	0	82.9	3.9	4.2
	0.5%	1.2	62.9	1.2	4.6
	1%	0.9	68.4	1.9	4.8
	1.5%	0.6	64.1	6.2	5.6
Poly Khadi CPL	Control	0	96.1	2.6	3.0
	0.5%	11.6	50.5	4.3	5.0
	1%	3.2	52.3	2.1	4.4
	1.5%	2.5	55.2	2.4	4.4
CPH	Control	0	101.0	2.6	1.8
	10%	2.7	72.0	4.5	3.6
	15%	2.0	69.9	3.3	4.0
	20%	1.9	70.2	4.2	4.00

Table 10: Drapeability of cotton *khadi* fabrics treated with varying concentration of Cellulase

Fabric name and its codes	*Concentration of finish(W/W)*	*% weight loss*	*% drape coefficient*		*No. of nodes*
			M	*SD*	
Cotton Khadi CL	Control	0	90.5	5.3	3.6
	0.5%	0.5	65.8	2.4	4.2
	1%	0.5	65.8	1.9	4.2
CM	Control	0	70.2	3.3	4.6
	0.5%	1.9	50.8	4.0	4.8
	1%	1.6	44.9	3.9	5.4
CH	Control	0	82.9	3.9	4.2
	0.5%	0.3	60.5	4.0	5.2
	1%	0.3	55.5	4.2	5.0
Poly Khadi CPL	Control	0	96.1	2.6	3.0
	0.5%	1.5	47.3	2.8	5.0
	1%	6.3	47.6	2.4	5.2
CPH	Control	0	101.1	2.6	1.8
	0.5%	0.1	76.1	5.1	3.2
	1%	1.7	78.8	4.7	3.0

It is also observed that number of nodes increase with decrease in drape coefficient, because fabric become soft after treatment.

One way ANOVA is applied to find out the effect of cellulase enzyme concentration on drapability of different fabrics. Effect of concentration of cellulase enzyme finish on drapability is found significant at one percent level (F=2601.64). Thus concentration of finish significantly affects the drapability.

Effect of Amylase on Tearing Strength

Modification in tearing strength of finished and unfinished *khadi* fabrics with and without amylase enzyme treatment in warp and weft direction is given in Table 11. The tearing strength of light weight cotton *khadi* fabric is reduced after enzymatic treatment and the reduction is higher in warp direction than weft direction. On the other hand, improvement in tearing strength in all other *khadi* fabrics is seen.

Table 11: Tearing strength of *khadi* fabrics treated with varying concentration of Amylase

Fabric name and its codes	*Conc. of finish (W/W)*	*% weight loss*	*Bending length (cm)*				*Warp and weft average*
			Warp		*Weft*		
			M	*SD*	*M*	*SD*	
Cotton Khadi							
CL	Control	0	595.2	17.5	634.8	7.01	**615.0**
	10%	4.1	543.4	25.3	549.1	29.4	**546.2**
	15%	1.5	541.4	24.6	556.8	30.6	**549.1**
	20%	1.9	451.8	16.6	495.5	80.0	**473.6**
CM	Control	0	929.2	47.5	1064.9	106.4	**997.0**
	10%	3.2	988.1	57.5	1111.0	93.7	**1049.5**
	15%	8.1	972.8	83.4	1269.7	14.0	**1121.2**
	20%	10.5	1018.8	121.7	1198.0	63.7	**1108.4**
CH	Control	0	283.4	7.0	267.5	12.3	**275.4**
	10%	1.2	304.6	27.3	316.8	7.1	**310.7**
	15%	0.9	286.7	9.2	307.2	9.8	**296.9**
	20%	0.6	264.3	10.7	291.2	20.8	**277.7**
Poly Khadi	Control	0	441.6	57.2	484.8	34.5	**463.2**
CPL	10%	11.6	844.8	95.7	1093.1	185.4	**968.9**
	15%	3.2	842.2	152.6	1024.0	150.0	**933.1**
	20%	2.5	960.0	64.0	1216.0	64.0	**1088.0**
CPH	Control	0	847.3	21.0	903.6	47.5	**875.5**
	10%	2.7	908.8	70.1	960.0	27.1	**934.4**
	15%	2	852.4	64.3	996.6	62.7	**924.5**
	20%	1.9	814.0	44.7	926.0	23.2	**870.0**

The maximum and very sharp improvement is observed in enzyme treated lightweight cotton poly *khadi* fabric in both warp and weft direction. In other fabrics, marginal increase in strength is found. Surface properties of the treated fabrics show a significant reduction for enzyme treated fabrics.

ANOVA table shows that the effect of amylase on tearing strength with different fabrics at different concentrations is not significant that is, there is no significant difference between tearing strength of type of fabrics, concentration of fabrics and direction of fabric at one percent and five percent level. Only significant difference is found between fabric and warp and weft direction at one percent level (F=2.08).

Effect of Cellulase Enzyme on Tearing Strength

In case of cellulase enzyme treatment, a different trend is observed in the tearing strength loss values in Table 12. There is loss in strength of light weight cotton, light weight poly *khadi*, and heavy weight poly *khadi* fabrics. Slight loss in strength is observed in light weight poly *khadi* and heavy weight poly *khadi* but strength loss is substantial in light weight cotton *khadi*. On the contrary, medium weight cotton and heavy weight cotton *khadi* exhibit no significant change in strength.

Loss in tearing strength is due to the fact that hydrolysis of cellulose chain of fibers resulted in decrease in length of polymer chain of cellulose. This adversely affected strength of component fibers and yarns ultimately reducing tearing strength of fabric.

ANOVA results show that effect of fabric types on tearing strength is not significant. While effect of different concentration and fabric direction is significantly found at one percent and five percent level (F=12.41). Interaction between concentration of finishes and warp and weft direction is again significant (F=6.24) and interaction between fabric, concentration of finish and warp weft direction is also found significant (F=.13.23) Thus all three factors significantly affect the tearing strength of cotton *khadi* and poly *khadi* fabrics at one percent and five percent level (F=7.24)

Hand

Hand of fabrics was determined using the Kawabata Evaluation System. Only light weight cotton (CL), heavy weight cotton (CH) and light weight cotton polyester (CPL) samples treated with one percent concentration of finishes were selected for KES testing presented in Figure 1.

Compression Properties using Compression Tester (KES-FB3A)

Decrease in LC is seen in cellulase and amylase treated samples, and thus fabric becomes less compressible after enzyme treatments. Compressional resilience (RC) of cellulase and amy-

Table 12: Tearing Strength of *khadi* fabrics treated with varying concentration of Cellulase

Fabric name and its codes	*Conc. of finish (W/W)*	*% weight loss*	*Bending length (cm)*				*Warp and weft average*
			Warp		*Weft*		
			M	*SD*	*M*	*SD*	
Cotton Khadi	Control	0	595.2	17.5	634.8	7.0	**615.0**
Cl	0.5%	0.5	410.8	23.6	506.8	160.2	**458.8**
	1%	0.5	492.8	79.2	448.0	18.6	**470.4**
CM	Control	0	929.2	26.7	1102.4	106.4	**997.0**
	0.5%	1.9	926.7	47.5	1064.9	64.3	**1029.1**
	1%	1.6	900.0	32.1	1131.5	73.2	**1001.2**
CH	Control	0	283.4	7.0	267.5	12.3	**275.4**
	0.5%	0.3	264.3	1.2	291.2	32.1	**277.7**
	1%	0.3	251.8	7.4	276.0	4.5	**263.9**
Poly Khadi	Control	0	441.6	57.2	484.8	34.5	**463.2**
CPL	0.5%	1.5	419.8	41.1	565.7	38.0	**492.7**
	1%	6.3	416.0	51.0	533.7	53.0	**474.8**
CPH	Control	0	847.3	21.0	903.6	47.5	**875.5**
	0.5%	0.1	768.0	48.8	883.3	133.8	**825.6**
	1%	1.7	780.8	28.8	803.9	23.0	**792.4**

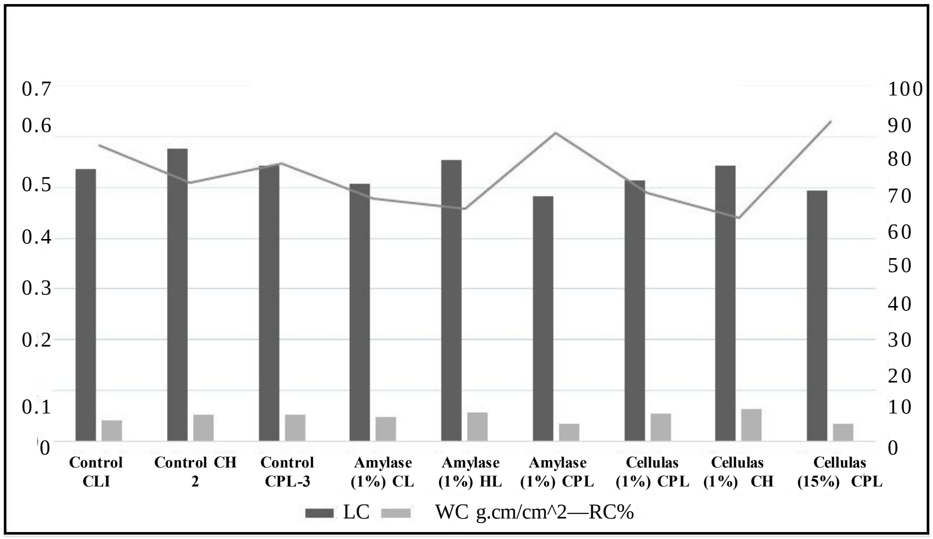

Fig. 1. Compresion properties using compression tester (KES-FB3A)

lase treated CPL sample increases as compared to control sample.

Fabric Weight and Thickness

It is clearly seen from the Figure 2 that after all finishing treatment fabric decreased in thickness. Minimum weight loss is found after enzyme treatment as compared to control sample.

Tensile Properties using Tensile Tester (KES-FB1A)

Tensile properties of cotton *khadi* and poly *khadi* fabrics treated with enzyme finishes are shown in Figure 3. LT and WT values of cellulase and amylase at one percent finish concentration have increased. Thus, these treated fabrics require more force during stretch under ten-

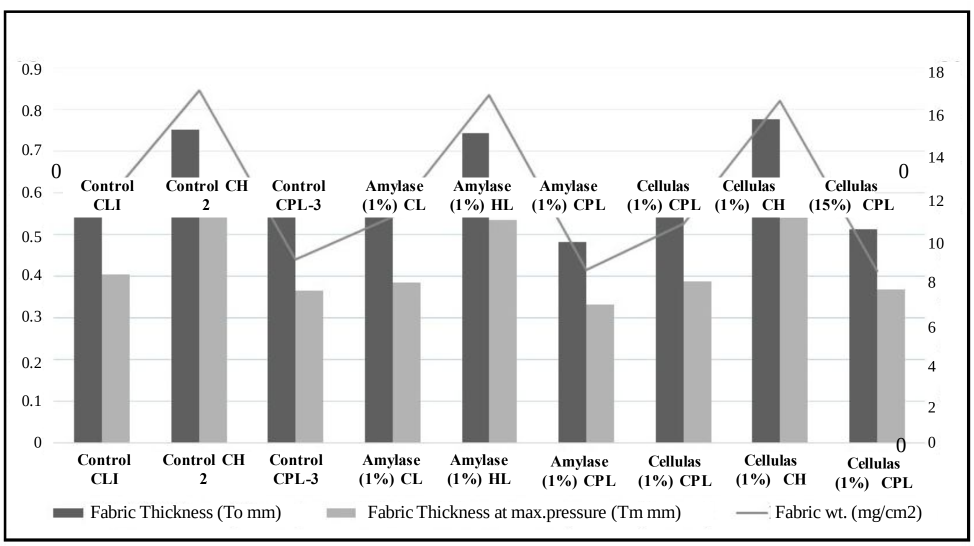

Fig. 2. Fabric weight and thickness

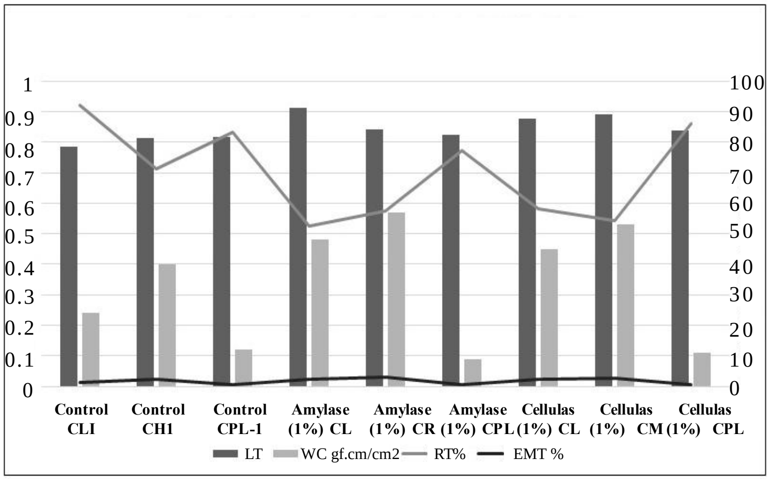

Fig. 3. Tensile properties using tensile tester (KES-FB1A)

sile load. EMT percentage value of these fabrics is also higher indicating increase in stretch ability after finishing treatment. RT percentage (tensile resilience) of light weight cotton *khadi and* medium cotton *khadi* fabrics decrease after enzyme treatments.

Shear Properties using Shear tester KES- FB1

The results analyzed above suggest that shear rigidity and shear hysteresis value of the treated samples increases substantially except in case of CPL. Changes in compression and shear properties of enzyme treated fabrics suggest that the fabrics become tight (Fig.4).

Bending Properties using Pure Bending Tester (KES-FB2)

Result in Figure 5 depicts considerable decrease in bending length of amylase and cellulase treated CL and CM fabrics as compared to

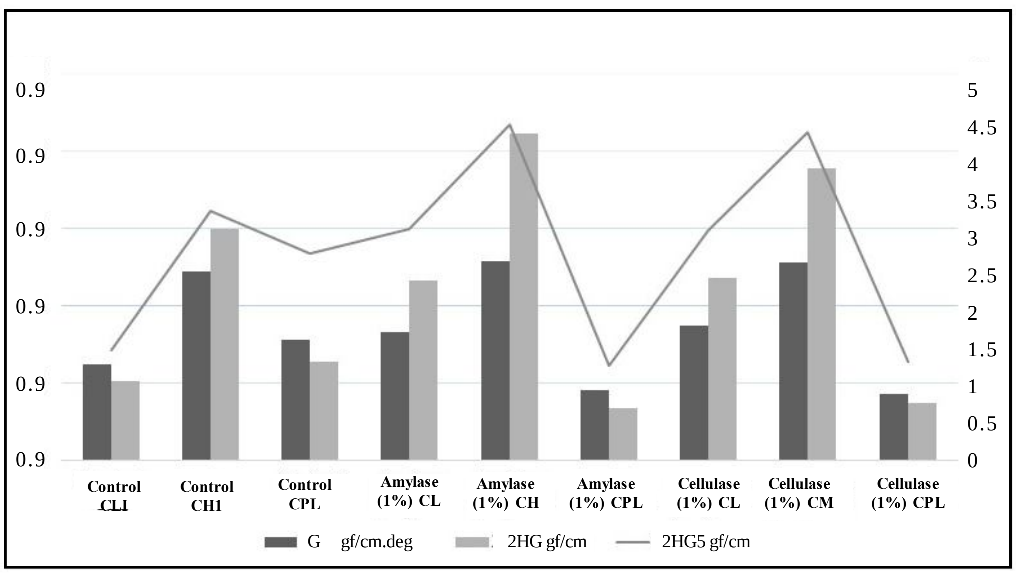

Fig. 4. Shear properties using shear tester KES-FB1

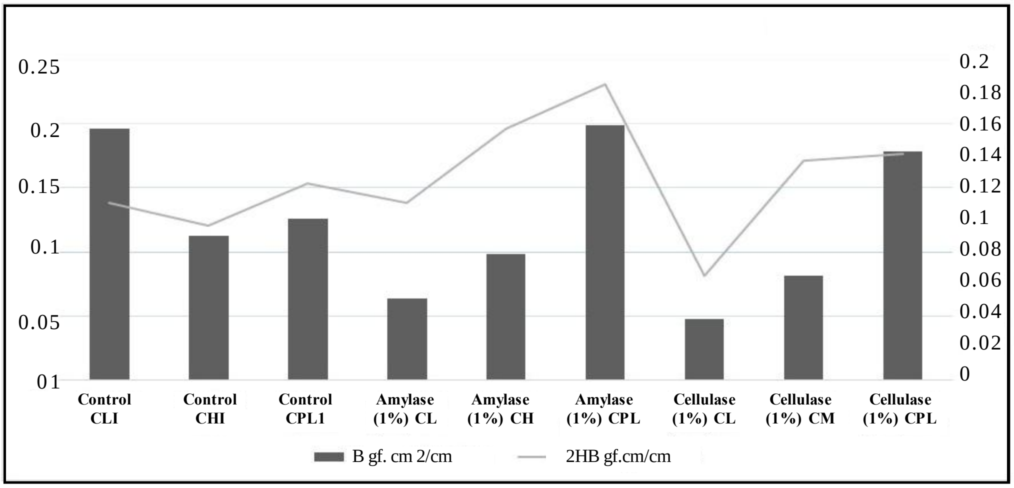

Fig. 5. Bending properties using pure bending tester (KES-FB2)

CPL fabrics that is, fabric becomes soft after one percent concentration of enzymatic treatment.

Surface Properties using Surface Tester (KES-FB4)

It is observed from the Figure 6 that treated samples show increase in MIU and MMD values, which correspond to high frictional property and larger variations in coefficient of friction respectively. MIU of amylase treated CL fabric is quite high. Similarly, MIU of cellulase treated CL, CM samples is also high at one percent concentration. SMD (surface roughness) of fabrics decreases.

Thus, it can be concluded that the surface of the treated fabric becomes smoother with enzyme treatment as indicated by the lower smooth-

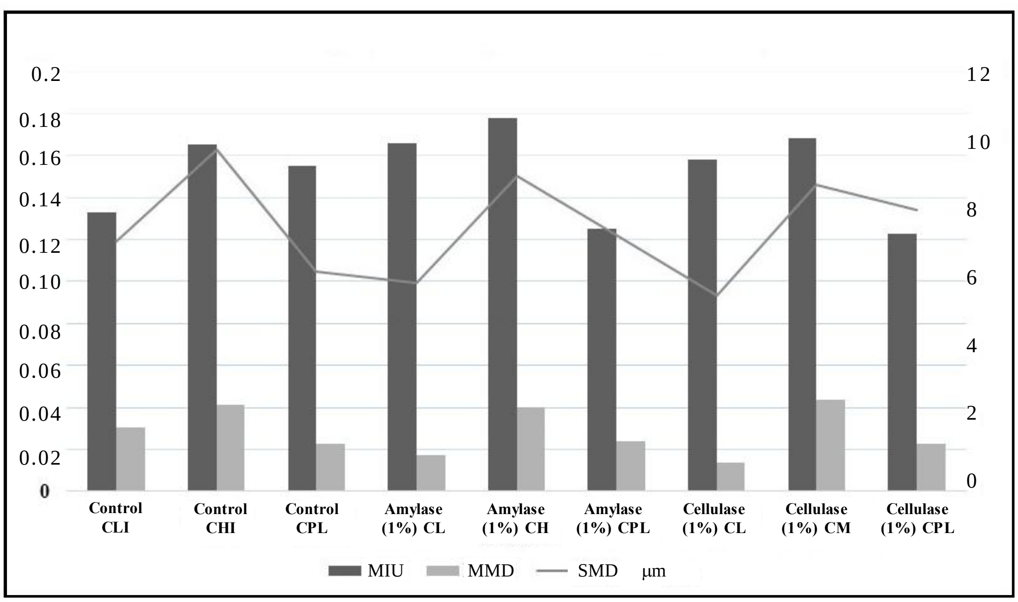

Fig. 6. Surface properties using surface tester (KES-FB4)

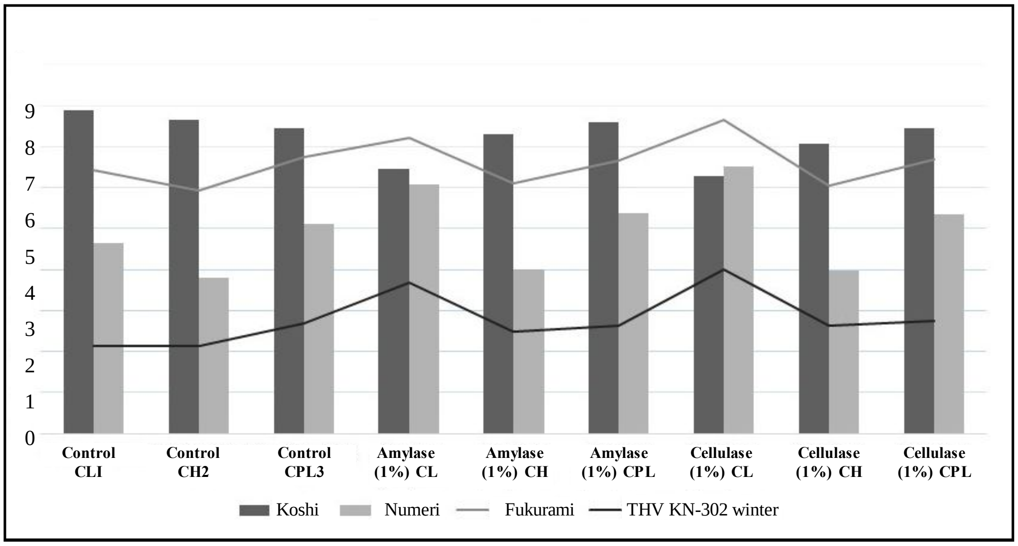

Fig. 6. Primary and total hand values

ness values, and reduced variability along the surface.

Primary and Total Hand Values

The primary hand values (Koshi, Numeri, Fukumari) and total hand value (THV) of the fabrics are estimated. During prediction of primary hand values, all the foregoing parameters are jointly combined and a single hand value is obtained. In a fabric, the Koshi depends on its bending properties. The primary Fukurami value is indicative of softness, fullness and compressibility. Numeri indicates smoothness of fabric surface.

It is clear from the Figure 7 that CL and CH samples finished with amylase and cellulase show lowest Koshi value as compared to CPL sample due to lowest bending stiffness. It is also found that amylase and cellulase treated samples obtain highest value of Fukurami.

Total hand value of fabrics is estimated from the primary hand values. It is observed from Figure 7 that enzyme treated samples show increase in THV values as compared to control samples.

CONCLUSION

In this experimental work, pure cotton and cotton polyester blend *khadi* were treated with cellulase and amylase, and consequently considerable improvement in softness was observed.

Decreased stiffness in all five fabrics was found in case of amylase and cellulase enzymes with all three concentrations. Stiffness of treated fabrics decreasing marginally as the concentration of finish is increase, while weight loss percentage decrease continuously.

The bending rigidity of finished and unfinished cotton *khadi* fabric and poly *khadi* fabrics with amylase and cellulase enzyme treatment significantly reduced after enzyme treatment in all finishing concentrations.

The cotton *khadi* medium weight fabrics treated with amylase enzyme shows maximum increase in wrinkle recovery angle in warp direction and weft direction over untreated fabrics. After finishing, cellulase enzyme treated cotton *khadi* medium weight fabrics showed uniform improvement in crease recovery angle in warp direction, while in weft direction treated fabrics showed better recovery than cotton *khadi* heavy and light weight treated ones when compared to corresponding unfinished fabrics.

Percent drape coefficient is sharply decreased as the concentration of amylase is increased. In case of cellulase enzyme it is also observed that number of nodes increased with decrease in drape coefficient, because fabric became soft after treatment.

After finishing with amylase cotton poly *khadi* and cotton heavy weight fabrics showed better tearing strength in both warp and weft direction. While in case of cellulase enzyme treatment higher loss is observed in warp way, while it is less in weft direction.

Cellulase and amylase treated fabrics showed remarkable reduction in bending and shear rigidity and also in bending hysteresis. Consequently, these treatments improved the flexibility of the fabrics as marked by low Koshy values.

Cellulase and amylase treated fabrics exhibited high degree of elasticity in bending and shear as measured by the low values of bending and shear hysteresis.

Cellulase and amylase treated fabrics displayed higher tensile energy (WT) and extensibility (EMT) and consequently, lower resiliency values (RT) among the fabrics in group 1.

Compressional energy (WC) and compressibility were observed to be higher for cellulase treated fabric, which too contributed to higher Fukurami (fullness and softness) value.

MMD and SMD values for cellulase and amylase treated fabrics were lowest indicating a smoother surface topology. Hence, these fabrics exhibited highest Numeri (smoothness) values.

By virtue of highest flexibility, extensibility, smoothness and fullness and softness values, cellulase treatment could be graded as the best (highest THV), followed closely by amylase treated fabric.

RECOMMENDATIONS

The procedure and results can be used for teaching and curriculum, as an application of finish on garment. Similar studies can be carried out on all the varieties of *khadi* blended fabrics in order to develop market viable new products.

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REFERENCES

Booth JE 1968. *Principles of Textile Testing*. 3rd Edition. London: Newness-Butterworth.

Cusick et al. 1963. Physical properties of some commercial non-woven fabrics-the use of drapemeter for investigating the properties of non-woven fabrics. *Journal of Textile Institute*, 54-52.

Dhurai Bharathi 2007. Effect of enzyme softening of cotton hosiery yarns on knitability and dimensional properties of weft knitted fabrics. *Indian Journal of Fiber and Textile Research*, 32(2): 241-247.

Joseph ML 1986. *Introductory Textile Science*. 5th Edition. New York: C.B.S. College Publishing.

Karmarkar SR 1999. *Chemical Technology in the Pretreatment Processes of Textile*. 1st Edition. Elsevier: Netherlands Publishing.

Patel C, Kumar A 1994. Enzymatic treatment of manmade cellulosic fabrics. *Genencor International*, 26(10): 25-28.

Paulo-Cavaco A, Guebitz G 2003.Textile processing with enzymes. *Textile Journal International England*, 66-69.

Peirce FT 1930. The “handle” of cloth as a measurable quantity. *Journal of the Textile Institute*, 21(9): 377.

Schindler DW, Hausen 2004. *Chemical Finishing of Textiles*. England: Woodhead Publishing in Textiles Cambridge.

Shenai VA, Saraf NM 1995. *Technology of Textile Finishing*. Mumbai: Sevak Publications.

Official Home Page of Zhu Riyao 1999. Effect of Enzyme Treatment on Yarn Properties, National Textile Center Annual Report (Online) (updated at 08/07/90). From <http://www. P2pays.Org/ref/pdf/com> (Retrieved on 12 May 2010).