Bio Polishing of Knit Goods

By: Prof. S.K. Laga, Prof. Dr. A.I. Wasif & Mr. Karan Shah

Textile & Engineering Institute, Ichalkaranji

Abstract

The appearance and handle of cotton knits can be significantly improved by treatment with celluloses. Such treatment leads to the removal of surface hairs from fabric and improve brightness of dyed fabric. The effect of treatment is long lasting. Handle of fabric is improved due to increased smoothness, better drapeability, reduced stiffness and rigidity of the fabric.

Enzymes are effective under a particular pH range, time, concentration, temp and liquor ratio. We have made an attempt to optimize these variables and obtain best results using 3% Cellusoft-SO in an acidic pH (4-5) at 55 ^{0}C temperature for 50 minutes keeping 1:10 M : L ratio.

1. Introduction

In the recent years enzymes have found a variety of uses in textile applications. Popular uses are stone washing of denims and surface modification of cellulosic fabrics to improve their appearance and handle. The process of treating with cellulases is termed as Bio-polishing. In case of denims we can get stone wash effect without using pumice stones by using enzymes. Another advantage of using enzymes is that, these are environment friendly, since they are readily biodegradable. Besides, they will not leave chemical residue on the processed materials and the colour changes on the dyed goods are very less[1].

Knitted goods treated with enzymes are free from surface hairiness and neps with much improved handle and flexibility. The fabric surface becomes smoother and more lustrous[2]. There is also a lower tendency to further pilling possibly due to the fact that there are less protruding fibre ends from the yarns after the enzyme application.

Bio-finishing also called bio-polishing, is a finishing process applied to cellulose textiles that produces permanent effects by the use of enzymes. Bio-finishing removes protruding fibres and slubs from fabrics, significantly reduces pilling, softens fabric hand and provides a smooth fabric appearance, especially for knitwear and as a pretreatment for printing. Second rate articles can obtain the high value eye appeal of first rate ones[3]. In denim processing, bio-finishing can reduce or eliminate abrasive stones and the aggressive chlorine chemistry, achieving the desired “worn” looks. Bio-finishing is not only useful for cotton but also for regenerated cellulose fabrics, especially for lyocell and microfiber articles. By incorporating enzymes into detergents to remove protruding surface fibres, improved colour retention is achieved after multiple launderings. The disadvantages of bio-polishing are the formation of fibre dust, which has to be removed thoroughly, the reproducibility of the effect (which is dependent upon many parameters) and in the worst case, loss of tear strength[4].

Enzymes are high molecular weight proteins produced by living organisms to catalyse the chemical reactions essential for the organism’s survival. They have complex three-dimensional structures composed of long chains of amino acids with molecular weights ranging from 10,000 to about 150,000 and occasionally to more than 10,00,000. These naturally occurring molecules provide a high degree of catalytic specificity unmatched by man-made catalysts. The enzyme and substrate form a ‘lock and key’ complex that requires the enzyme to have a specific molecular alignment in order to act as a catalyst[4,5]. The lock and key theory of Emil Fischer was broadened by Koshland Jr to the induced-fit theory of the enzyme-substrate-complex. Chemical reactions catalysed by enzymes can typically be carried out, as is most usual in nature, under mild aqueous conditions without the need for high temperatures, extreme pH values or chemical solvents. What a dream for every chemist[6,7]

Cellulases:

Cellulases are high molecular colloidal protein bio-catalyst in metabolite form. Industrial cellulases represent complex of a number of cellulases, cellobiase and related enzymes of completely non uniform composition in a molecular weight range of 10,000 to 4 million[8].

Enzymes or cellulases have a protein like structure with primary, secondary, tertiary and quaternary structures and that are susceptible to degradation due to temperature, ionizing radiation, light, acids, alkali, and biological effect factors.

Cellulases are capable of breaking the 1,4-B-glucoside bond of cellulose randomly. When cotton fabric is treated with a cellulase solution under optimum condition: Cellulase hydrolyse cellulose by reaching to the 1,4-B-glucoside bond of the cellulose molecule[9].

As a result of which the fabric surface becomes smooth with the loss of surface fibres and the hand becomes soft[10]. There is also loss in strength proportional to the amount of weight reduction.

There are mainly three types of cellulases:

1) Acid stable (more effective in pH range of 4.5 – 5)
2) Neutral stable (effective at pH 7)
3) Alkaline stable (not used widely)

Action of Cellulase:

Enzymes are large molecular complex and can't penetrate interior of the fabric. Hence enzyme action takes place preferentially on the surface. Where cleavage of cellulose chain occurs, Microfibrils which are loose fibres break off under the influence of bio-catalytic degradation and results in better mechanism or modify the surface of the fabric.

Enzymes contain activity centre in three dimensional structure form namely fissures, holes, pockets, cavities, hollows[11].

These enzymes first of all form an enzyme substance complex on the surface of the cellulose.

Bio-reaction then takes place in the above mentioned substrate mentioned enzyme substrate complex.

Finally, the complex disintegrates with the release of the reaction products and the original enzymes which are once again available.

Enzyme Inactivation:

To prevent any damage of the fabric after the finishing operation it is very essential that the reaction be terminated at the end of treatment by enzyme inactivation [12]. If the enzyme is not inactivated entirely then at the end of the reaction fibres get damaged and even extreme cases total destruction of the material may result. The enzyme inactivation is therefore of great importance from the technical point of view.

There are two distinct process of termination of enzyme:

1) Hot treatment at 80 ^{0}C for 20 min.
2) By raising the pH to 11–12.

Chemistry of enzyme finishing:

More than with other chemical reactions, the enzyme catalysed hydrolysis of cellulose is strongly influenced by factors such as pH, temperature, time and agitation. The optimal pH for a particular cellulase depends upon its origin. Trichoderma-based products (sometimes called 'acid cellulases') work best at pH 4.5 – 6, whereas cellulases from Humicola (often called 'neutral cellulases') are more effective at pH 6 – 6.5. The reaction temperature is also critical since at low temperatures, the reaction rate is slower than desired, but very high temperature can deactivate the enzyme by providing enough energy to alter its molecular alignments and thereby destroy its catalytic ability[13,14]. Since enzymes are true catalysts and are not consumed during the chemical reaction, the hydrolysis reaction will continue until either the reaction conditions change or the cellulose is physically removed from the reaction mixture. Mechanical agitation is important in order for the hydrolysis reaction to proceed efficiently. Recent work has demonstrated that the kinetics of the reaction are controlled by mass transfer effects. The absorption-desorption mechanism of enzyme action depends on agitation to remove hydrolysis by-products and expose new fibre areas to attack.

Because the enzyme's catalytic action is not reduced during the reaction, effective methods of ending the hydrolysis must be employed to prevent excessive fibre loss. Since the molecule's physical alignments are crucial to its catalytic ability, procedures that alter the cellulase molecule's internal structure can be used to deactivate the catalysis and halt the hydrolysis. High temperatures (> 70 ^{0}C or 160 ^{0}F for at least 20 min or short drying at 120 ^{0}C or 248 ^{0}F), high pH (>10) and high electrolyte content as well as enzyme poisons can serve to terminate the reaction by distorting the enzyme's molecular shape.

Recent developments is enzyme manufacturing have led to commercial products that contain a preponderance of one cellulase component. These 'mono-component' enzymes are produced from modified Humicola strains and are primarily endo-glucanases active at pH 7 – 7.5 and are referred to as 'alkaline cellulases'.

Processing of bio-polishing of garments:

- Fill the machine with water
- Add nonionic wetting agents (0.2 to 0.3 gpl)
- Adjust pH 4.5 to 5.5 with acetic acid
- Add 2 gpl lubricant (non-ionic)
- Load the garments in the machine and run the machine for 30 minutes at 45 – 50 ^{0}C
- Remove one garment from the machine and compare with the unwashed garment to see the effect of bio-polishing
- If bio-polishing is satisfactory, raise the temperature gradually to 85 ^{0}C and maintain the temperature for 10 minutes to deactivate the enzyme
- Drain the liquor
- Cold rinse for 5 – 10 minutes followed by hydro extraction and tumble dry

Advantages of using enzymes for bio-polishing:

- Hairiness, fluffs and pills are removed.
- Material sticking (the burr effect) is prevented.
- Improved handle.
- Achievement of surface smoothness and a clear structural appearance.
- Improved lustre.
- Material texture relaxation
- Increased flexibility and therefore a soft handle, even with over end products and mercerized fabric.
- Improved sewability.
- Fast to washing, low pilling tendency, no napping in use, or during care operation.
- Stone wash effect without pumice stone and dyestuff destroying chemicals.
- Poor quality, uneven, napped, knoppy material surface (i.e.) typical second quality goods are converted into elegant, lustrous, soft, top quality with a fine, high quality surface appearance.

Disadvantages of this finishing technique:

- Loss in weight
- Loss in strength

Cellulases have been used on a large scale for years in medicine analysis, food chemistry and other industries.

Troubleshooting for bio-finishing:

As mechanical agitations important to effect the bio-finishing, only selected processes and machines can be used, for example tubular fabric preferably cut to open width and treated in open width washers. In the rope form the loosened fibre particles are filtered out by the fabric and cannot easily be removed. The pad-batch process, jig or package dyeing machines are not effective in bio-finishing[15].

Not all cellulase enzymes give identical results, even with similar fabrics in similar equipment. Cellulases derived from Trichoderma typically are the most aggressive in their action, whereas mono-component endo-glucanases often require the most mechanical action to achieve the desired effects. Slow deactivation of the cellulases during transport and storage can adversely affect the reproducibility of the resulting effects. If cotton is not washed carefully before bio-finishing, secondary fibre compounds as residual biocides can deactivate the cellulases. The same is true for natural or synthetic tannic acids, and resist or fastness improving agents for wool or nylon in cellulose fibre blends.

Deactivation of cellulases after the desired effects have been achieved is very important. If the enzyme is not completely removed from the fabric, or is not effectively deactivated, the hydrolysis reaction will continue, although at a slower rate. As very large molecules, cellulases cannot diffuse into the crystalline parts of the cellulose fibres. They react on the fibre surface, so fibre damage takes time. But eventually enough hydrolysis will have taken place to weaken the affected fabrics or garments, leading to customer complaints and returns[15].

Undesirable deactivation may be caused by high temperature and time, for example, caused by transport and storage and also by enzyme poisons such as certain surfactants (especially cationic ones), formaldehyde-containing products or heavy metal ions. An activation effect on cellulases was reported by Nicolai and co-workers. Alkaline pretreatment, low concentrations of selected non-ionic surfactants, polycarboxylic acids and polyvinyl pyrrolidone can enhance the bio-finishing of celluloses.

The use of pH buffers during the hydrolysis reaction is strongly recommended, especially when abrading denim fabrics. Cellulase enzymes have very narrow pH ranges of effectiveness and denim fabrics can have significant quantities of residual alkali from the indigo dyeing process. Buffers are required to maintain the appropriate reaction conditions for maximum enzyme effectiveness.

Because the effect of processing auxiliaries on cellulase catalysis is difficult to predict, it is important to evaluate any changes in processing formulas carefully by conducting small scale trials before making significant changes in production procedures.

Removal of protruding fibers from garment surface using cellulase enzymes is called bio-polishing. These enzymes are proteins and capable of hydrolyzing cellulose (cotton). In bio-polishing they act upon the short fibers protruding from fabric surface and make the fibers weak which are easily removed during washing. This process imparts soft and smooth feel and reduces fuzz or pilling tendency. This process is applicable to garments made of cotton and its blends[16].

Two kinds of cellulases are commercially available, acid cellulases which have activity in acidic medium in pH range of 4.5 – 5.5 and neutral cellulases which have activity in pH range of 5.5 – 8.0. Both these types are active in the range of 45 ^{0}C to 60 ^{0}C.

2. Materials and Methodology:

2.1 Materials Used:

Material used	:	Knitted Fabric (100% cotton)
Type	:	Single Jersy
Type	:	32
Grey width	:	36”
CPI	:	42
WPL	:	46
GSM	:	140

2.2 Details of Chemicals:

1. Hydrogen Peroxide (50%)
2. Sodium Hydroxide
3. Cidascour LTJ (Solvent)
4. Sodium Carbonate
5. Lissapol D (Wetting agent)
6. Hydrose (Reducing agent)
7. Sodium hexametaphosphate (Sequestering agent)
8. Sodium silicate (Stabilizer)
9. Urea (Hygroscopic agent)
10. Sodium Chloride
11. Acetic acid (Buffer)

2.3 Dyes Used:

Reactive Navy Blue HER
Reactive Red HE4R
Drimarene Orange KGL

2.4 Enzyme Used:

Cellusoft-SO which has an activity of 750 EGU/gm. It is an acid stable cellulase, produced by submerged fermentation of a trichoderma micro-organism.

2.5 Pretreatment:

a. Scouring:

Recipe:

Sodium Hydroxide	:	2.5%
Sodium Carbonate	:	1%
Cidascour LTJ	:	0.5%
Wetting Agent	:	0.5%
Sodium hexametaphosphate	:	0.2%
Temperature at boil	:	80 ^{0}C
Time	:	4 – 5 hours
pH	:	9 – 10
M : L	:	1 : 20

b. Bleaching:

Recipe:

Hydrogen Peroxide (50%)	:	0.5 – 1%
Sodium Silicate	:	1%
Sodium hexametaphosphate	:	0.2%
Temperature	:	85 ^{0}C
Time	:	2 hours
pH	:	10–10.5
M : L	:	1 : 20

Process Sequence:

Grey fabric → Cold wash → Scouring at boil → Hot wash → Hot wash → Cold wash →

Peroxide Bleach at 85 ^{0}C → Hot wash → Hot wash → Cold wash → Drying

c. One bath scouring and Peroxide bleaching:

Recipe:

Sodium Hydroxide	:	2.5%
Lissapol D	:	0.5%
Hydrogen Peroxide	:	2 – 3%
Sodium Silicate	:	1.5%
Sodium hexametaphosphate	:	0.2%
Temperature	:	80 ^{0}C
Time	:	2 – 3 hours
pH	:	10 – 10.5
M : L	:	1 : 20

Process Sequence:

Grey fabric → Cold wash → Scouring and Peroxide Bleaching at boil → Hot wash →
Hot wash → Cold wash → Drying

2.6 Dyeing:

Recipe:

Dye	:	Light shade (0.5%), Medium shade (1.5%) & Dark shade (3%)
Salt	:	60gpl
Soda ash	:	15gpl
Temperature	:	80 – 85 ^{0}C
Time	:	2 hours
M : L	:	1 : 15
pH	:	8.5 – 9.5

After Treatment:

Hot wash → Hot wash → Soaping at boil for 15–20 min. → Cold wash →
Souring with acetic acid (2gpl) for 15 to 20 min at 45–55 ^{0}C → Cold wash

Process sequence:

a. Dyeing followed by bio-polishing:

Well scoured and bleached sample → Dye addition → Salt addition (2 instalment)
→ Soda ash addition (2 instalment) → Dyeing → Hot wash → Hot wash →
Soaping (at boil) → Hot wash → Cold wash → Enzyme treatment → Cold wash
→ Drying

b. Bio-polishing before dyeing:

Well scoured & bleached sample → Bio-polishing → Cold Wash → Drying → Dye addition
→ Salt addition → Addition of Soda ash → Hot wash → Hot wash → Soaping →
Hot wash → Cold wash → Drying

2.7 Process Variables:

a) Concentration
b) Temperature
c) pH
d) Time
e) M : L Ratio
f) Mechanical Agitation

To achieve optimum bio-polishing, the process variables have been varied as mentioned below.

a) Concentration of enzyme: 0.5%, 1%, 2%, 2.5%, 3% & 4%.
b) Temperature : 40 ^{0}C, 45 ^{0}C, 50 ^{0}C, 55 ^{0}C & 60 ^{0}C.
c) pH : 3-4, 4-5 & 5-6.
d) M : L : 1:5, 1:10, 1:15 & 1:20.
e) Mechanical Agitation: Vigorous Stirring, Medium Stirring & Without Stirring.

3. Testing & Analysis:

The following tests have been carried out to assess the properties of bio-polished cotton knitted fabric.

i) Wash fastness (ISO-3), ii) Abrasion resistance, iii) Weight loss, iv) Pilling, v) K/S value using C.C.M.

4. Results and Discussion:

Factors affecting bio-polishing:

Bio-polishing is affected by many factors. Major ones are Enzyme, Type of Fabric and Process Variables.

The predominant process variables which control the bio-polishing are Temperature, pH, Duration of treatment, Material to liquor ratio, Enzyme concentration and Mechanical agitation.

To find the effect of above mentioned factors we have carried out the bio-polishing by following ways.

1) Keeping M : L ratio, pH and temperature constant and varying the concentration of enzyme.
2) Keeping temperature and pH constant and varying the material to liquor ratio.
3) Keeping M : L ratio constant and varying the temperature.
4) Keeping temp. and M : L Ratio constant and varying the pH of solution.
5) Keeping all these parameters constant and varying the duration of treatment.

Effect of Concentration:

Concentration of enzyme is a major factor which affects the performance of the bio-polishing of the knitted fabric.

There are different types of enzymes available in the market. Each enzyme has an optimum concentration, pH and temperature range.

In our study, we have used CELLUSOFT-SO, which is an acid stable cellulase. By varying the concentration of cellulase and keeping the other parameters, such as pH, temperature, time and material to liquor ratio constant, we have observed that the best bio-polishing can be obtained at the following conditions :

M : L Ratio	:	1 : 10
Temperature	:	55 ^{0}C
Time	:	50 min.
pH	:	4 – 5

To observe the effects of conc. of Enzyme on bio-polishing, we have treated knitted fabric with various concentrations of Cellusoft-SO viz. 0.5%, 1%, 1.5%, 2%, 2.5%, 3% and 3.5%. Results obtained are depicted in Table 1.

Table 1: Effects of concentration of enzyme on bio-polishing

Properties	Result						
	Concentration of Enzyme						
	0.5%	1%	1.5%	2%	2.5%	3%	3.5%
Weight loss (%)	0.36	0.77	0.88	1.46	2.09	2.12	2.07
Abrasion (mm)	0.04	0.06	0.07	0.08	0.08	0.09	0.09
Wash fastness	4-5	4-5	4-5	4-5	4-5	4-5	4-5
Pilling rating	3	3	4	4	4	4	4

From this table, it can be concluded that as the concentration of cellulase increases from 0.5% to 2.0%, weight loss increases significantly. Optimum percentage weight loss is obtained at 3% conc. Increase in conc. of enzyme causes an increase in strength loss. Fabric thickness is reduced with increase in conc. of enzyme.

Hence 3% conc. of enzyme is the optimum dose.

Effects of Temperature:

Temperature affects the performance of cellulase. Each enzyme has an optimum temperature range where enzyme activity is maximum. Hence it is essential to determine the optimal temperature. Increase in temperature decreases the enzyme activity rapidly and the enzyme action comes to almost zero and the enzymes are permanently deactivated at 70 ^{0}C. Low temperature shows reduction in reaction speed but does not deactivate the enzyme. It is therefore possible to use a lower temperature by a longer cycle. The activity of Cellusoft-SO at 40 ^{0}C is only 50%. It is also observed that every 10 ^{0}C rise in temperature doubles the activity of enzyme, as long as it is not deactivated.

To observe the effects of temp. on bio-polishing, we have treated knitted fabric with the following recipe. Results obtained are depicted in Table 2.

Recipe:

M : L Ratio	:	1 : 10
Conc.	:	3%
Time	:	50 min.
pH	:	4 – 5

Table 2: Effects of temperature on bio-polishing

Properties	Results			
	Temperature			
	40 ^{0}C	45 ^{0}C	50 ^{0}C	55 ^{0}C
Weight loss (%)	0.75	1.03	1.45	2.56
Abrasion (mm)	0.04	0.06	0.07	0.08
Wash fastness	4-5	4-5	4-5	4-5
Pilling rating	3	4	4	4

The optimum result is obtained at 55 ^{0}C temperature.

Effects of pH:

pH is also a critical factor affecting the efficiency of bio-polishing. A particular type of cellulase is most effective and can be operated at a certain specific pH range.

To observe the effects of pH on bio-polishing, we have treated knitted fabric with 3% Cellusoft-SO at various pH viz. 3-4, 4-5, 5-6, 6-7 & 7-8. Results obtained are depicted in Table 3.

Table 3: Effects of pH on bio-polishing

Properties	Results				
	pH				
	3-4	4-5	5-6	6-7	7-8
Weight loss (%)	0.47	1.21	1.1	0.93	0.86
Abrasion (mm)	0.03	0.08	0.06	0.05	0.04
Wash fastness	3	4	4	3	3
Pilling rating	3	4	4	4	4

We have observed that the activity of enzyme is maximum at pH 5 – 5.5. But optimum bio-polishing effect is obtained at pH 4-5.

Effects of M : L Ratio:

M : L Ratio has a substantial effect on bio-polishing. As the liquor ratio increases the bath conc. of cellulase decreases, and the fabric weight loss decreases. The dilution affects substantially enzymatic activity.

To observe the effects of M : L ratio on bio-polishing, we have treated knitted fabric with 3% Cellusoft-SO at various M : L ratios viz. 1:5, 1:10, 1:15 & 1:20.
Recipe :

Temperature : 55 ^{0}C
Concentration : 3%
Time : 50 min.
pH : 4 – 5

Results obtained are depicted in Table 4. From this table, it is found that as the liquor ratio increases the pilling rating of treatment sample decreases. At the low M : L Ratio, the fabric show very low pilling and at higher M : L Ratio, pilling tendency of fabric is more. Thus, pilling rating goes on increasing with increases in liquor ratio.

Table 4: Effects of M : L Ratio on bio-polishing

Properties	Results			
	M : L Ratio			
	1:5	1:10	1:15	1:20
Weight loss (%)	1.06	1.12	0.62	0.51
Abrasion (mm)	0.03	0.04	0.06	0.06
Wash fastness	4-5	4-5	4	4
Pilling rating	4	4	3	3

The best result is obtained at 1 : 10 M : L Ratio.

Effects of duration:

To observe the effects of duration of enzyme treatment on bio-polishing, we have treated knitted fabric with 3% Cellusoft-SO for various durations viz. 30 min., 40 min., 50 min. & 60 min.
Recipe :

Temperature : 55 ^{0}C
Concentration : 3%
M : L Ratio : 1 : 10
pH : 4 – 5

Results obtained are depicted in Table 5.

Table 5: Effects of duration on bio-polishing

Properties	Results			
	Time (min)			
	30	40	50	60
Weight loss (%)	0.72	1.01	1.42	2.48
Abrasion (mm)	0.04	0.06	0.07	0.07
Wash fastness	4-5	4-5	4-5	4-5
Pilling rating	3	4	4	4

The best result is obtained at 50 min treatment time.

Effects of Enzyme treatment on Dyeing property:

To observe the effects of enzyme treatment on dyeing property, bio-polishing of cotton knitted fabric has been carried out before dyeing as well as after dyeing.
Recipe for Enzyme treatment:

M : L Ratio : 1:10
Temperature : 55 ^{0}C
Time : 50 min.
pH : 4 – 5
Conc. : 3%

The results obtained are tabulated in Table 6.

Table 6: Effects of Enzyme treatment on dyeing property (3% shade)

Properties	Results					
	Enzymes treatment after dyeing			Enzyme treatment before dyeing		
	Concentration of Enzyme					
	1%	2%	3%	1%	2%	3%
Weight loss (%)	0.77	1.23	1.89	0.79	1.25	1.93
Abrasion (mm)	0.04	0.07	0.08	0.05	0.06	0.09
Wash fastness	4	4-5	4-5	2-3	3	3-4
Pilling rating	3	4	4	3	4	4
K/S Values	9.6	8.9	8.1	9.9	9.9	9.9

From the above table, it is seen that the properties of pre-dyed enzyme treated sample have been compared with the properties of pre-enzyme treated dyed sample.

Dyeing with reactive dyes after enzyme treatment results in somewhat deeper shade. It is due to the surface modification of the knitted fabric before dyeing. This fabric shows poor wash fastness and rubbing fastness than the pre-dyed enzyme treated sample. The pre-enzyme treatment does not make any difference in softness and surface modification as compare to pre-dyed enzyme treated sample

The best result is obtained at 50 min treatment time.

One bath Bio-polishing and dyeing:

Enzymatic cellulose degradation is also possible during reactive dyeing. Here the dyeing process as well as bio-polishing will be affected. Number of washes, time, cost and energy can be saved by this one bath method. However, it should be noted that there is some reduction in colour yield of reactive dyeing. This is because reactive dyeing is carried out in acidic pH during bio-polishing. But precaution is taken during addition of soda-ash as reactive dyes require alkaline condition for its fixation. The fabric is made neutral before adding soda-ash. It is found that neutral stable enzymes are more suitable in this type of one bath treatment.

Recipe:

Conventional Method	One Bath Method
Conc. of Enzyme : 3%	Conc. of Enzyme : 3%
M : L Ratio : 1:10	MLR : 1:10
Temp. : 55 ^{0}C	Temp. : 55 ^{0}C
Time : 50 mins.	Time : 2.5 – 3 hrs.
pH : 4-5	

5. Conclusions:

- The best result is obtained at 3% concentration of enzyme.
- 1:10 M : L ratio gives the best result.
- At pH range of 4-5, enzyme shows maximum activity.
- At 55 ^{0}C temperature, enzyme activity is maximum.
- Mechanical agitation supports enzyme activity.
- Depth of shade increases when enzyme treatment is given before dyeing and the depth decreases when enzyme treatment is given after dyeing.
- Pilling tendency decreases with application of enzyme.
- One bath application saves energy, time & cost. But the bio-polishing effect is not as good as the two bath method.
- Wash fastness of the enzyme treated sample before dyeing is very poor.
- Wash fastness of the enzyme treated sample after dyeing is good.
- Wash fastness of one bath enzyme treated sample is moderate.

Acknowledgement

The authors are thankful to Prof. (Dr.) C.D. Kane, Executive Director, Textile & Engineering Institute, Ichalkaranji for his kind permission to publish this paper.

References

1) Hobberg T and Thumm S. ‘Finishing of lyocell – part 3’, Melliand International, 1999, 5(1), 83-85.
2) Breier R. ‘Rein enzymatische Antifilzausrtistung von Wolle nach dem Lanazym-Verfahren’, Melliand Textilberichte, 2000, 81(4), 298-302.
3) Stohr R, ‘Enzyme- Biokatalysatoren in der Textilveredlung’, Melliand Textilberichte, 1995, 76(11), 1010-1013.
4) Etters, J N, Annis P A, American Dyestuff Reporter, 1998, 87(5) 1823.
5) Enzyme Nomenclature, Amsterdam-London-New York, Elsevier, 1973.
6) Stewart C W, Book of Papers, 1996 AATCC International Technical Conference & Exhibition, Nashville, TN, AATCC, Research Triangle Park, NC, 1996, 212-217.
7) Nono’s Handbook of Practical Biotechnology, Boyce COL (ed.), Bagsvared, Denmark Novo Industries A/S, 1982, 77-81.
8) Lee Y and Fan L T, Biotechnolgy and Bioengineering, 1982, 24(11), 2383-2406.
9) Buschle-Biller G and Traore M K, Textile Research Journal, 1998, 68(3), 185-192.
10) Sarker A and Etters J N, AATCC Review, 2001, 1(3), 48-52.
11) Cavaco-Paulo A, Almedia L and Bishop D, Textile Research Journal, 1996, 66(5), 287-294.
12) Li Y and Hardin I, Textile Chemist and Colorist, 1998, 30(9), 23-29.
13) Ueda M, Koo H and Wakida T, Textile Research Journal, 1994, 64(10), 616-618.
14) Technical Manual of the American Association of Textile, Chemist and Colorist, Amercian Association of Textile Chemists and Colorists, Research Triangle Park, NC, 1999.
15) Nicolai M and Nechwatal A, ‘Einflussfaktoren beim Biofinish-Prozess’, International Textile Bulletin, 2002, 48(6), 52.
16) Nicolai M, Nechwatal A and Miek K P, ‘Biofinish-Prozesse in der Textilveredlung’, Textilveredlung, 1993, 34(5/6), 19-22.