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Enzymatic Pre-Treatment as a Means of Enhancing the Colorfastness Properties of Handloom Cotton Fabrics

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Abstract:
Cotton is produced in over 50 countries worldwide, averaging 20-24 million tons per year. India is one of the largest consumers of cotton, accounting for about 60% of the total consumption of cotton. Demands in handloom fabrics are increasing throughout the world due to their comfort in wearing particularly in the tropical countries. Hence, to make this sector internationally and globally competitive, it requires maintaining standard quality parameters. Fortunately, in the present time, commercially viable alternative methods for preparing and finishing cotton fibre substrates based on the use of enzymes have emerged. Such methods will ensure the supremacy of cotton over other fibers for decades to come. The present research was planned by keeping in view the emerging trend of bio-processing, use of swelling agents and dyeing with natural dyes. The present study was conducted to optimize the pre treatment process with enzymes and swelling agents on handloom cotton fabric. Experiments were conducted to determine optimum values of four variables for acid and neutral cellulase enzyme treatment, namely, pH, concentration, treatment time and temperature. Concentration, treatment time and temperature were the three variables optimized for the swelling agents. Dyeing variables i.e. concentration of dye material, extraction time, dyeing time, mordant concentration and method of mordanting with natural mordant were optimized.

Keywords: Handloom cotton, *Butea frondosa,* Myrobolan, Colourfastness

1.0 Introduction:
Cotton is produced in over 50 countries worldwide, averaging 20-24 million tons per year. India is one of the largest consumers of cotton, accounting for about 60% of the total consumption of cotton (Furter *et al.,* 2007).The annual reports of handloom and handloom sector present a sorrowful picture of piling up of stocks in godowns as the marketability and consumer preference for hand woven products failed to stand for the glittering attractions of mill made textiles. The main reason behind such a non preference of handloom fabrics might be attributed partially to higher maintenance cost for washing, ironing, partly for rough texture and less durability (Sarvani and Balakrishnaiah, 2007). Fortunately, in the present time, commercially viable alternative methods for preparing and finishing cotton fibre substrates based on the use of enzymes have emerged. Such methods will ensure the supremacy of cotton over other fibers for decades to come (Sarkar and Etters, 2004). The term cellulase refers to a group of enzymes that act synergistically to hydrolyse cellulose (Karmakar, 1998). Cellulase is also highly effective in removing loose fibres from fabric surfaces a process known as biopolishing. Enzymes plays an important role in textile processing (Ammayappan, 2013). The enzymatic treatment of textiles significantly improves some of their properties as well as increases their aesthetic values and comfort of use (Anna and Lipp, 2011). Modification of fabric improves dyeability but the discharge of toxic, non -biodegradable substances as effluent pollute the environment and it is becoming a serious concern for textile industries (Sundrarajan *et. al*, 2012). Bhuiyan *et.al*, 2014 investigated the

dyeability and color performance of chitosan treated cotton fabric. The action of swelling agents inherits the outer skin on cotton fibers and causes it to split and form collars; the inner cellulose layers swell rapidly the collars (Fan *et al*, 1987). Due to loosening of crystalline region of cellulose by swelling agents, the absorbency of the fabric towards water and dyes is increased. Das *et al.* (1997) carried out experiment on scoured and bleached fabrics and pretreated separately with four swelling agents, viz., NaOH, EDTA, urea and phosphoric acid, and the consequent changes in tensile properties, extent of decrystallization, absorbency, dye uptake and fastness to washing, light and rubbing for a monochlorotriazine reactive dye (C. I. Reactive Orange 13) were evaluated. Wakida *et al.* (2000) treated desized and scoured cotton fabric in a two-step process with sodium hydroxide/liquid ammonia and liquid ammonia/sodium hydroxide to investigate the effect of the treatment sequence.

Lokhande (2003) used dye ability to study the swelling mechanisms of intra- and intermicellar swelling agents on cotton cellulose. Reactive and direct dye were used for dyeing, and zinc chloride, ethylenediamine (EDA), and morpholine were used for swelling reactions. Venkatraman *et al.* (2003) subjected cotton cellulose to repeated swelling treatment with aqueous solutions of ethylenediamine (EDA). Warwicker and Clayton (2003) assessed the reactivity of scoured Acala 4-42 cotton before and after treatment with alkaline and acid swelling agents. Nair (2006) studied the changes in fine structure of native cotton cellulose as a result of three typical swelling treatment viz., with Sodium hydroxide (NaOH), Ethylenediamine (EDA) and Zinc chloride ($ZnCl_2$). Constanta *et al.* (2006) examined the influence of some swelling agents with reduced water content on final properties of cotton fabrics.
Kumar *et al.* (1997) treated several cellulosic fabrics with a whole cellulase, a mixture of exo and endo-activities, and a cellulase enriched for a particular type of endo-glucanase activity. Linen was the most susceptible to enzymatic hydrolysis followed by viscose rayon, cotton and lyocell. Gulrajani *et al.* (1998) carried out experiments to find out the optimum conditions for the use of cellulase enzyme on cotton knitted fabric. Ibrahim *et al.* (1999) evaluated the impact of enzymatic pretreatment using acid-cellulases on the dyeability of cellulosic substrates with direct and reactive dyes.

Chattopadhyay and Sharma (2000) investigated the effect of cellulase enzyme (Biosoft-P) on 100% jute fabrics under different conditions. Buschle-Diller and Traore (1998) subjected cotton fabric to enzymatic hydrolysis with cellulases before and after dyeing. The effects of direct dyes of increasing molecular size on the rate of the enzymatic hydrolysis reaction were investigated, along with mono-and bi-functional reactive dyes with different multi-functional groups. RamKumar and Abdalah (2001) treated the cotton fabric with Cellusoft™ AP enzyme at six different concentration levels. The study investigated the effect of different concentration levels of cellulase enzymes on the frictional properties of fabrics. Teli *et al.* (2004) subjected the cotton to swelling treatment using three different swelling agents like sodium hydroxide, ethylene diamine and morpholine. Suman and Khambra (2005) investigated the effect of cellulase enzyme with different concentrations and time periods on tensile strength of two qualities of denim i.e. 100% cotton denim (light weight denim and heavy weight denim) and blended cotton denim (synthetic denim). Patra and Arora (2006) made an attempt to study the effect of a commercially available scouring enzyme on cotton under different conditions. The results showed that the average absorbency time in majority of the samples was less than or around 3 seconds.

Thakare (2006) studied the treatment of hydroxylamine sulphate at various concentrations and temperatures on moisture regain and dye uptake on cotton fibre. Tsatsaroni and Kyriakides (1995) dyed cotton and wool fabrics with the natural dyes chlorophyll and carmine after treatment with the enzymes cellulase, α-amylase and trypsin. Kyriakides *et al.* (1998) used natural pigments from Crocus sativus stigmas for the dyeing of cotton and wool fibres after treatment with the enzymes α-amylase and trypsin, respectively. Tsatsaroni *et al.* (1998) conducted experiment for dyeing cotton and wool fibres after enzymatic treatment with the crude water extract of saffron stigmas
(Suri *et al.* (1999) dyed silk with Tesu dye and concluded that with increase in concentration of the dyes the colour value increases. Gulrajani *et al.* (2003) used red sandalwood extract as a dye for wool and nylon. A commercial lipase preparation (Lipolase) was examined as a scouring agent for cotton fabrics by Kalantzi, 2010.

Vankar *et al.* (2007) carried out research on two step ultrasonic dyeing of cotton and silk fabrics with natural dyes.
Thus, the present research was planned by keeping in view the emerging trend of bio-processing, use of swelling agents and dyeing with natural dyes. The present study was conducted to optimize the pre treatment process with enzymes and swelling agents on handloom cotton fabric. Experiments were conducted to determine optimum values of four variables for acid and neutral cellulase enzyme treatment, namely, pH, concentration, treatment time and temperature. Concentration, treatment time and temperature were the three variables optimized for the swelling agents. Dyeing variables i.e. concentration of dye material, extraction time, dyeing time, mordant concentration and method of mordanting with natural mordant were optimized. The colour fastness properties against washing, light, rubbing and perspiration of both the untreated and the enzymatically and swelling agents treated and dyed samples were evaluated and compared. Estimation of the cost effectiveness for the adoption of the pre treatments and dyeing was accomplished by conducting cost estimation. The cost of dyeing of one metre of untreated and pretreated handloom cotton with cellulases and swelling agents was calculated.

2.0 Materials and Methods:

Pure white handloom cotton fabric was procured from "Gandhi Ashram" of local market in Pantnagar (Uttarakhand). The fabric specifications i.e. the fabric count, weight per unit area and thickness of the chosen material for the study was calculated. Commercial acid cellulase enzyme (Americos Cellscos 450AP) and neutral cellulase enzyme (Americos Cellucom 110 OM) was used for the present research work. Sodium hydroxide, Ethylenediamine and Zinc chloride were the three swelling agents used for the treatment of handloom cotton. *Butea frondosa* (Tesu dye) dye was selected for the research. The optimum pH, concentration, treatment time and temperature selected for the acid cellulase enzyme treatment were 5.5, 1.5% (owf), 45 minutes and 50°C, respectively whereas in case of neutral cellulase enzyme, it was 7.5, 2.0% (owf), 70 minutes and 70°C respectively. The optimum concentration, treatment time and temperature selected for Sodium hydroxide treatment were 20% w/v, 60 minutes and 60°C, respectively. In case of Ethylenediamine, 80% w/v, 60 minutes and 70°C were selected as optimum concentration, treatment time and temperature, respectively. In case of Zinc chloride treatment, the optimum concentration, treatment time and temperature were selected as 80% w/v, 60 minutes and 70°C, respectively. In case of *Butea frondosa* 5 g of myrobolan with simultaneous mordanting and dyeing method was used. Weighted mean score was calculated for quantifying the ratings of colourfastness. The fastness to washing was given highest weight 4 since it is most important followed by fastness to light, rubbing and perspiration which were given weight 3, 2 and 1, respectively.

2.1 Evaluation of Colourfastness of dyed samples

2.1.1 Light fastness test (IS: 686-1957:

Test pieces of 1 x 6 cm size were cut and mounted on a metal frame, one below the other along with 8 blue wool patterns ranging in light fastness from rating no. 1 (very low light fastness) frame was covered with an opaque cover so that each test piece was half exposed. The frame was placed inside the exposure rack and fading was carried out as per the test no IS: 686-1957. The control and the dyed samples were checked after every 2 hours until the contrast between the exposed and unexposed positions became equivalent to grade 3 on the gray scale.

2.1.2 Washing fastness test (IS: 3361-1979):

A specimen of 10 x 4 cm was placed between the two adjacent fabrics, one of cotton and other of wool and sewed along four sides to form a composite specimen. A soap solution with 5 g of soap in one litre of distilled water was prepared. Test was carried out as per the recommendations of IS: 3361-1979 (Test 2) in a Launderometer. Each composite sample was placed in separate containers and soap solution previously heated at 50 ± 2°C was added to each container maintaining material to liquor ratio of 1:50. These specimens were treated for 45 minutes at 50 ± 2°C.After removing this composite specimen from launderometer, it was rinsed twice in cold water and then in running tap water for 10 minutes and squeezed. Stitching was removed along the two long sides and one short side and the composite specimens were opened out and dried in air at a temperature not exceeding 60°C.Change in colour of the treated test specimen and the degree of staining of the two pieces of adjacent was evaluated with the help of geometric gray scales. AATCC (1975) rating scale was used for assigning washing fastness scores for change in colour and degree of staining.

2.1.3 Rubbing Fastness (IS: 766:1956):

Two test specimens of size not less than 14 x 5 cm from each sample were drawn for dry and wet rubbing test. The test specimens were then evaluated for change in colour and the undyed cotton cloth was evaluated for degree of staining using geometric grey scale.

2.1.4 Perspiration fastness (IS: 971-1956):

A test piece of 5 x 4 cm was drawn from the test samples and placed between 5 x 5 cm piece of wool and cotton (as done for preparing composite specimen in case of wash fastness test).Acidic test liquor was prepared by dissolving 2.65 gm of sodium chloride (NaCl) and 0.75 gm of urea per litre and adjusting the pH of the solution to 5.6 with the addition of acetic acid. Alkaline test liquor was prepared by dissolving 3 gm of sodium chloride per litre and adjusting the pH of the solution to 7.2 with the addition of sodium chloride. Each composite specimen was wetted thoroughly in the acidic test liquor using liquor to specimen ratio of 50:1 (ml/g) and allowed to remain in the liquor for 30 minutes. The liquor was poured off and the specimen was placed between two glass plates under the force of 4.5 g. These glass plates (along with specimen) were then kept in the perspirometer and the apparatus was placed in an air over for 4 hours at 37 ± 2°C. At the end of this period, specimen were removed, separated and dried in air at a temperature not exceeding 60°C.Each composite specimen was treated similarly using alkaline test liquor also. The test pieces were evaluated for change in colour whereas the undyed cotton and undyed wool samples were evaluated for degree of staining using geometric gray scales.

3.0 Results and Discussion:

3.1 Colourfastness properties for *Butea frondosa* dye Light fastness of samples treated with cellulase enzymes, swelling agents and dyed with *Butea frondosa* dye without mordant

The samples were rated for fastness to light with the help of blue wool standard and the assessment was done by comparing the exposed and unexposed portion of the samples. Eight point scale was used to evaluate the light fastness of the dyed samples.It is evident from the table 1 that in case of *Butea frondosa* dye the untreated sample was rated as poor (2). All the samples treated with cellulase enzymes and swelling agents showed fair (3) light fastness, except the samples treated with Ethylenediamine and Zinc chloride which were rated as poor (2). It was found that as compared to untreated handloom cotton dyed with *Butea frondosa* dye all the treated samples showed improvement in light fastness except Ethylenediamine and Zinc chloride treated samples.

3.2 Wash fastness of samples treated with cellulase enzymes, swelling agents and dyed with *Butea frondosa* dye without mordant

Dyed samples were tested against the washing fastness and rated on the basis of change in colour as well as degree of staining on adjacent fabric (wool and cotton).It is evident from the table 1 that in case of *Butea frondosa* dye, the change in colour of untreated sample was between considerable to noticeable (2-3). Wool and cotton showed considerable (2) staining in case of *Butea frondosa* dye. Samples treated with Ethylenediamine and Zinc chloride showed between considerable to noticeable (2-3) change in colour, whereas other samples treated with cellulase enzymes and swelling agents showed noticeable (3) colour change. Staining on wool was found to be noticeable (3) in case of samples treated with Neutral cellulase and Sodium hydroxide, Ethylenediamine and Zinc combined with neutral cellulase treatment, whereas other treated samples showed between considerable to noticeable (2-3) staining on wool. Staining on cotton was found to be between considerable to noticeable (2-3) in case of Zinc chloride treated sample, while noticeable (3) staining on cotton was found by rest of the treated samples.

Table 1 Effect of enzymatic and swelling agents treatment on colourfastness properties of handloom cotton dyed with *Butea frondosa* dye without mordant

S. No.	Samples	LF	WF			RF						PS						WMS	Rank
			CC	CS		Dry			Wet			Acid			Alkaline				
				W	C	CC	CS		CC	CS		CC	CS		CC	CS			
							W	C		W	C		W	C		W	C		
1.	Untreated	2	2-3	2	2	2	2	2	2	2	2	3	3	3	3	3	3	2.16	VIII
2.	Acid cellulase	3	3	2-3	3	3	3	3	2-3	3	3	3-4	3	3	3	3	3	2.92	V
3.	Neutral cellulase	3	3	3	3	3	3	3	3	3	3	4	3	3	3	4	4	3.05	I
4.	Sodium hydroxide	3	3	2-3	3	3	3	3	2-3	3	3	4	3	3	3	3	3	2.93	IV
5.	Ethylenediamine	2	2-3	2-3	3	3	3	3	2-3	3	3	3-4	3	3	3	3	3	2.55	VI
6.	Zinc chloride	2	2-3	2-3	2-3	2-3	3	3	2-3	3	3	3-4	3	3	3	3	3	2.47	VII
7.	Sodium hydroxide + Acid cellulase	3	3	2-3	3	3	3	3	3	3	3	4	3	3	3	3	3	2.94	III
8.	Ethylenediamine + Acid cellulase	3	3	2-3	3	3	3	3	3	3	3	4	3	3	3	3	3	2.94	III
9.	Zinc chloride + Acid cellulase	3	3	2-3	3	3	3	3	3	3	3	4	3	3	3	3	3	2.94	III
10.	Sodium hydroxide + Neutral cellulase	3	3	3	3	3	3	3	3	3	3	4	3	3	3	3	3	3.01	II
11.	Ethylenediamine + Neutral cellulase	3	3	3	3	3	3	3	3	3	3	4	3	3	3	3	3	3.01	II
12.	Zinc chloride + Neutral cellulase	3	3	3	3	3	3	3	3	3	3	4	3	3	3	3	3	3.01	II

LF = Light fastness, WF = Washing fastness, RF = Rubbing fastness, PF = Perspiration fastness, CC = Change in colour, CS = Colour staining, W = Wool, C = Cotton, WMS = Weighted mean score

Table 2 Effect of enzymatic and swelling agents treatment on colourfastness properties of handloom cotton dyed with *Butea frondosa* dye and mordanted with Myrobolan

S. No.	Samples	LF	WF			RF						PS						WMS	Rank
			CC	CS		Dry			Wet			Acid			Alkaline				
				W	C	CC	CS		CC	CS		CC	CS		CC	CS			
							W	C		W	C		W	C		W	C		
1.	Untreated	3-4	3-4	4	4	3-4	4	4	3-4	4	4	3-4	4	4	3-4	4	4	3.73	III
2.	Acid cellulase	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4.00	II
3.	Neutral cellulase	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4.00	II
4.	Sodium hydroxide	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4.00	II
5.	Ethylenediamine	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4.00	II
6.	Zinc chloride	3-4	3-4	4	4	3-4	4	4	3-4	4	4	3-4	4	4	3-4	4	4	3.73	III
7.	Sodium hydroxide + Acid cellulase	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4.00	II
8.	Ethylenediamine + Acid cellulase	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4.00	II
9.	Zinc chloride + Acid cellulase	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4.00	II
10.	Sodium hydroxide + Neutral cellulase	4-5	5	4-5	4-5	4	4	4	4	4	4	4-5	4	4	4-5	4	4	4.43	I
11.	Ethylenediamine + Neutral cellulase	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4.00	II
12.	Zinc chloride + Neutral cellulase	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4.00	II

LF = Light fastness, WF = Washing fastness, RF = Rubbing fastness, PF = Perspiration fastness, CC = Change in colour, CS = Colour staining, W = Wool, C = Cotton, WMS = Weighted mean score

Table 3: Costs per metre of handloom cotton pre treated with cellulases and swelling agents and dyed by using *Butea frondosa* without mordant

Items	Cost/unit	Amount used	Costs (Rs)				
			AC	NC	NaOH	EDA	$ZnCl_2$
Fabric	**90/metre**	**1metre**	**90**	**90**	**90**	**90**	**90**
AC	450/kg	150 gm	67.5	-	-	-	-
NC	750/kg	200 gm	-	150	-	-	-
NaOH	300/kg	1000 gm	-	-	300	-	-
EDA	600/litre	4000 ml	-	-	-	2400	-
$ZnCl_2$	390/kg	4000 gm	-	-	-	-	1560
Butea frondosa dye	700/kg	250 gm	175	175	175	175	175
Electricity charge	3.15/unit	-	11.02 (3.50a unit)	12.28 (3.90a unit)	11.81 (3.75a unit)	11.81 (3.75a unit)	11.81 (3.75a unit)
Labour (literate)	95/8hour	-	41.56 (3.50b min)	46.31 (3.90b min)	44.53 (3.75b min)	44.53 (3.75b min)	44.53 (3.75b min)
Total costs	-	-	385.08	473.59	621.34	2721.34	1881.34

AC=Acid cellulase, NC=Neutral cellulase, NaOH= Sodium hydroxide, EDA= Ethylenediamine, $ZnCl_2$ =Zinc chloride
1. Figures in parenthesis with subscript letter a and b indicates units of electricity used in the treatment process and labour time, respectively.

Table 4: Costs per metre of handloom cotton pretreated with cellulases and swelling agents and dyed by using *Butea frondosa* dye and simultaneous mordanted with Myrobolan

Items	Cost/unit	Amount used	Costs (Rs)				
			AC	NC	NaOH	EDA	$ZnCl_2$
Fabric	90/metre	1metre	90	90	90	90	90
AC	450/kg	150 gm	67.5	-	-	-	-
NC	750/kg	200 gm	-	150	-	-	-
NaOH	300/kg	1000 gm	-	-	300	-	-
EDA	600/litre	4000 ml	-	-	-	2400	-
$ZnCl_2$	390/kg	4000 gm	-	-	-	-	1560
Butea frondosa dye	700/kg	250 gm	175	175	175	175	175
Myrobolan	90/kg	250 gm	22.50	22.50	22.50	22.50	22.50
Electricity charge	3.15/unit	-	11.02 (3.50a unit)	12.28 (3.90a unit)	11.81 (3.75a unit)	11.81 (3.75a unit)	11.81 (3.75a unit)
Labour (literate)	95/8hour	-	41.56 (3.50b min)	46.31 (3.90b min)	44.53 (3.75b min)	44.53 (3.75b min)	44.53 (3.75b min)
Total costs	-	-	407.58	496.09	643.84	2743.84	1903.84

AC=Acid cellulase, NC=Neutral cellulase, NaOH= Sodium hydroxide, EDA= Ethylenediamine, $ZnCl_2$ =Zinc chloride
1. Figures in parenthesis with subscript letter a and b indicates units of electricity used in the treatment process and labour time, respectively.

3.3 Rubbing fastness of samples treated with cellulase enzymes, swelling agents and dyed with *Butea frondosa* dye without mordant

The dyed samples were rated for dry and wet rubbing fastness using geometric grey scales for change in colour as well as degree of staining on adjacent fabric. The results in the table 1 reveals that the untreated samples of *Butea frondosa* dye showed considerable (2) change in colour and considerable (2) staining on wool and cotton during dry rubbing test.It is evident from the table 1 that change in colour was between considerable to noticeable (2-3) in case of samples treated with Zinc chloride, whereas noticeable (3) colour change was observed in all the other treated samples. All the treated samples showed noticeable (3) staining on both wool and cotton in case of dry rubbing tests.In case of wet rubbing test, untreated samples showed considerable (2) change in colour and considerable (2) staining on wool and cotton was found.Samples treated with Acid cellulase, Sodium hydroxide, Ethylenediamine and Zinc chloride showed between considerable to noticeable (2-3) change in colour, whereas other treated samples showed noticeable (3) change in colour. All the treated samples showed noticeable (3) staining on wool and cotton. It was found that the wet rubbing fastness was better than the dry rubbing fastness.

3.4 Perspiration fastness of samples treated with cellulase enzymes, swelling agents and dyed with *Butea frondosa* dye without mordant

The dyed samples were rated for colourfastness to both acidic and alkaline perspiration, with respect to change in colour and degree of staining on wool and cotton. In case of *Butea frondosa* dye, the results showed that the change in colour and staining on wool and cotton for untreated sample was noticeable (3) in both acidic and alkaline perspiration (table 1).In acidic perspiration, the samples treated with Acid cellulase, Ethylenediamine and Zinc chloride showed between noticeable to slight (3-4) change in colour, whereas the other treated samples showed slight (4) change in colour. However in alkaline perspiration all the treated samples showed noticeable (3) change in colour.Staining on wool and cotton was found to be noticeable (3) in acidic perspiration on all the treated samples, while in case of alkaline perspiration all the treated samples showed noticeable (3) staining on wool and cotton, except the samples treated with Neutral cellulase which showed slight (4) staining on wool and cotton. It was observed that the treated samples were more fast to acidic perspiration than alkaline perspiration.

On the basis of weighted mean score, handloom cotton samples pretreated with cellulases, swelling agents and with their combinations and dyed with *Butea frondosa* dye without mordants were given rank for their fastness.In case of handloom cotton dyed with *Butea frondosa* dye without mordant, sample treated with Neutral cellulase obtained first rank. The second rank was secured by samples treated Sodium hydroxide, Ethylenediamine and Zinc chloride when combined with Neutral cellulase. The third rank was occupied by samples treated with Sodium hydroxide, Ethylenediamine and Zinc chloride when combined with Acid cellulase. Fourth, fifth, sixth and seventh rank was secured by samples treated with Sodium hydroxide, Acid cellulase, Ethylenediamine and Zinc chloride, respectively. The last eighth rank was obtained by untreated sample.

3.5 Light fastness of samples treated with cellulase enzymes, swelling agents and dyed with *Butea frondosa* dye and mordanted with Myrobolan

It is evident from the table 2 that the untreated mordanted sample showed change in colour between fair to fairly good (3-4) in case of *Butea frondosa* dye when tested for light fastness. Similarly, the sample treated with Zinc chloride also showed between fair to fairly good (3-4) light fastness, but the sample treated with Sodium hydroxide plus neutral cellulase enzyme was rated between fairly good to good (4-5). The other treated samples showed fairly good (4) light fastness. This indicated that the sample treated with combination of Sodium hydroxide plus neutral cellulase enzyme improved the light fastness of the dyed fabric which may be accepted by the consumers.

3.6 Washing fastness of samples treated with cellulase enzymes, swelling agents and dyed with *Butea frondosa* dye and mordanted with Myrobolan

Table 2 depicts that in case of *Butea frondosa* dye, the colour of untreated mordanted sample was changed between noticeable to slight (3-4). Slight (4) staining was shown on both wool and cotton. The maximum rating was observed by sample treated with Sodium hydroxide plus neutral cellulase i.e. negligible (5) change in colour as well as slight to negligible (4-5) staining on wool and cotton. Zinc chloride treated sample showed between noticeable to slight (3-4) change in colour which was same as of untreated sample. It shows that no improvement in wash fastness was observed with Zinc chloride treatment. All the other treated samples showed slight (4) change in colour and slight (4) staining on wool and cotton.

3.7 Rubbing fastness of samples treated with cellulase enzymes, swelling agents and dyed with *Butea frondosa* dye and mordanted with Myrobolan

It is depicted in the table 2 that the untreated mordanted samples showed between noticeable to slight (3-4) change in colour, whereas slight (4) staining on both wool and cotton was observed during both dry and wet rubbing test.All the treated samples showed slight (4) change in colour, except sample treated with Zinc chloride which showed between noticeable to slight (3-4) change in colour which was same as of untreated mordanted sample. All the treated samples showed slight (4) staining on wool and cotton in case of both dry and wet rubbing tests. The above tests indicated that no improvement was found in Zinc chloride treated sample, but other treated samples showed improvement in rubbing fastness as compared to untreated samples.

3.8 Perspiration fastness of samples treated with cellulase enzymes, swelling agents and dyed with *Butea frondosa* dye and mordanted with Myrobolan

The perspiration fastness of untreated sample dyed with *Butea frondosa* dye and mordanted with Myrobolan showed between noticeable to slight (3-4) change in colour and slight (4) staining on wool and cotton was observed in both acidic and alkaline perspiration [Table 2].

In both acidic and alkaline perspiration, Zinc chloride treated sample showed between noticeable to slight (3-4) change in colour, while the sample treated with Sodium hydroxide plus neutral cellulase showed between slight to negligible 4-(5) change in colour. All other treated samples showed slight (4) colour change. Slight (4) staining was observed on wool and cotton in both acidic and alkaline perspiration. The ratings of both acidic and alkaline perspiration showed that best improvement occurred in sample treated with Sodium hydroxide plus neutral cellulase whereas no improvement was found in Zinc chloride treated sample as compared to untreated mordanted sample. In case of handloom cotton dyed with *Butea frondosa* dye and mordanted with Myrobolan, it was found that the sample treated with Sodium hydroxide plus Neutral cellulase secured the first rank. All the other treated samples with cellulases, swelling agents and with their combinations secured second rank, except the samples treated with Zinc chloride and untreated mordanted sample which obtained third rank. This showed that Zinc chloride treatment had no effect on the improvement of colourfastness property in case of *Butea frondosa* dye mordanted with Myrobolan.

3.9 Estimated cost of dyeing of pretreated handloom cotton

The cost of dyeing of one metre of untreated and pretreated handloom cotton with cellulases and swelling agents using *Butea frondosa,* without mordant as well as with natural mordants were calculated. The cost of dyeing and pretreatment process was calculated including cost of fabric, dye, mordant, cellulases, swelling agents, labour and electricity charges (Table 3 and 4).

4.0 Conclusion:

The enzymatic pretreatment of the textiles are not aggressive to fibres and environment. The 'clean chemistry' approaches is an advantage in comparison to the powerful alkalies, acids, oxidizers and reducers needed in traditional processes tending to attack the textile material as well as causing considerable contamination in the environment. The residues of enzymes are present only in the form of primary structure and there are no chemical residues likely to affect the skin. Besides, they do not leave chemical residues on the processed materials and the colour change of the dyed is minimal. Although the dyeing costs increased with the pretreatment with cellulases, swelling agents as well as with their combinations, but nowadays the use of cellulases in the pretreatment process has found much broader acceptance as the effect of the treatment is long lasting and eco-friendly in nature. The pretreatment with swelling agents with optimized conditions enhances the physical properties as well as colour strength and colourfastness properties. Thus, some of the shortcomings of khadi cotton like rough texture, less dyeability and poor colourfastness can be minimized by chemical processing by an eco-friendly approach as well as using swelling agents in optimum conditions and can be recommended for handloom sectors as these sectors supports and strengthen the rural economy of our country.

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