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ORIGINAL RESEARCH

Effect of Combined Enzyme, Stone and Bleach Wash on Denim Fabrics

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Abstract

Denim pants are washed for giving different types of effects as per consumer requirement. In this study 78% BCI (Better Cotton Initiative) Cotton, 20% PIW (Post Industrial Waste) Cotton, 2% Lycra (Sample 1); 88% BCI Cotton, 10% PIW Recycled Cotton, 2% Lycra (Sample 2) and 92.5% BCI Cotton, 7.5% T- 400 (Sample 3) Denim Fabrics were washed by enzyme, stone and bleach consecutively. All the unwashed and washed samples were tested to determine their tensile strength, tearing strength, colorfastness to washing, colorfastness to rubbing, pH, and dimensional stability. All washed samples failed in the tensile test, but Sample 2 and 3 failed only in the tearing test. The colorfastness to washing and rubbing was considered to be good for the washed samples. For Sample 1 and 2 the dimensional change was quite high and all samples passed the pH test. It can be concluded that bringing a wash effect using enzymes, stones, and bleach on top of another drastically reduces the fabric's tensile and tearing properties, regardless of the percentage of different compositions.

1 | INTRODUCTION

Generally, denim is a 2/1 or 3/1 twill fabric which is made of indigo dyed warp yarn and undyed weft yarn. Denim in its raw form is stiff and rough in nature which needs special treatment to impart softness and smoothness for the wearer comfort. Denim products are washed for several purposes such as creating different styles, improving aesthetic properties and hand feel. Sometimes denim garments are also washed to remove impurities from it. To create different styles both wet and dry process are used in apparel industry. Denim is normally dyed with Indigo, Vat and Sulphur dyes which generally stay on fiber surface. As a result of mechanical and chemical process the dye from the fiber surface come out and creates different wash effects. Wet processes include acid wash, bleach wash, enzyme wash etc. while PP spray, sandblasting, grinding etc., are categorized under dry processes [1], [2].

Stone wash is used to create vintage and worn-out look. In stone washing, light weight pumice stones are used. Pumice stone are silica-rich and produced from the eruption and expulsion of earth [3]. One of the interesting features of pumice stones are that they float on water because of their high porosity and low density. Stones are loaded with denim garments in washing machine and the abrasion process scape off dye from the dyed yarn of warp yarn. Small sized stones do better abrasion than large sized stones. Moreover, small stone can provide more uniform abrasion effect [2]. The degree of abrasion in stone washing is not uniform which creates random pattern after washing. Pumice stones have some shortcomings like lack of reproducibility and more mechanical damage to machine. To overcome the problem nowadays synthetic stones are used [3]. Enzyme is a biochemical that is used in different textile processing such as desizing, scouring and washing. The main advantage of enzyme wash is that it is nontoxic and biodegradable. Cellulases enzymes, used in denim washing, solubilize the surface fiber of denim yarns and brings out the indigo dye from yarn. Cellulases break the cellulose chain at the middle and chain end depending upon its type. The activity of cellulases also depends on its nature (acid/neutral/basic) [1]. Enzyme wash came into play as a substitute of stone wash as the later has some environmental issues. At the end of washing cycle, enzymes are generally killed by increasing the temperature of washing bath to around 70 – 80 ℃ [3]. Bleach wash is done to fade the color of denim. It is very difficult to fade the color evenly from all over the garments without bleach wash. The problem with bleach wash is that the washing bath contains active chlorine compound which is not environment friendly. Another problem is that the chlorine destroys the cellulose which makes the cellulose yellowish if not neutralized properly [4].

The washing effect is diversified so much that not a single wash can bring the buyer's desired effect. traditional washing procedures include acid washing, enzyme washing, spray techniques, and stone enzyme washing using strong bleaching agents like potassium permanganate and sodium hypochlorite. Though cellulase enzymes have abrasion effect on denim, it is not up to the level of stone abrasion [5]. Again enzyme, stone and bleach, all three types of washing either fad the outlook or degrade the surface. But as the customer requirements and taste are changing so often due to the fast fashion culture, there may be required a combination of different types of washing procedures to bring the desired faded effect. The objective of this study is to find the effect of combined enzyme, stone and bleach wash on three different types of fabric and to investigate some commercially important physical and chemical properties of the treated samples.

2 | MATERIALS

2.1 Fabrication Details

For the study three different types of 3x1 right hand twill was collected from Standard Group. A summary of fabric specification of these fabric samples is given in Table 1.

Table 1: Fabrication details of samples

Description	Sample 1 (S1)	Sample 2 (S2)	Sample 3 (S3)
Overall fiber content	78% BCI Cotton, 20% PIW recycled cotton, 2% Lycra	88% BCI Cotton, 10% PIW recycled cotton, 2% Lycra	92.5% BCI Cotton, 7.5% T-400
Warp yarn count	6 N_e	8 N_e	12N_e + 10N_e
Warp yarn fiber content	70% BCI Cotton, 30% recycled cotton	85% BCI Cotton, 15% PIW recycled cotton	100% BCI Cotton
Weft yarn count	10N_e, 70D	12N_e, 70D	10 N_e + T-400
Weft yarn fiber content	96% BCI Cotton, 4% Lycra	95% BCI Cotton, 5% Lycra	95% BCI and T-400
Finished fabric EPI and PPI	56×49	66×51	80×45
Oz/yd^2	12	10.75	9.75

BCI = Better Cotton Initiative, PIW = Post Industrial Waste, T – 400 = 60% polyethylene terephthalate (PET) and 40% polytrimethylene terephthalate Bi-component fiber.

2.2 Chemicals

The three samples were washed by enzyme, stone and bleaching agent. The chemicals used in these washing processes are listed in the Table 2 as well. The chemicals listed below are calculated for 150 pcs denim pants. Along with the 150 pcs denims, the samples were washed as it is very much inconvenient to wash samples of small quantity. All the chemicals and stones were collected from Standard Group.

Table 2: Chemicals used for sample washing

Chemical category	Chemical name	Total quantity
Neutral enzyme	Recops Plus B	700 gm
Anti-back staining agent	Protect LCR (generic name was not disclosed by supplier)	4500 gm
Pumice stone	Stone (New + Old)	3 (18 kg each) + 4 (11 kg each) bags
Bleaching agent	Stable bleach (KCL)	1500-2000 gm
Basic chemical	Soda ash	500 gm
Neutralizing agent	Sodium meta bisulfite	1500 gm
Acid	Acetic acid	300 gm

2.3 Sample Preparation

By using the sample 1, sample 2 and sample 3 cylindrical shape structure was made by stitching to simulate the real washing action in denim pant. A model for the sample is given in Figure 1.

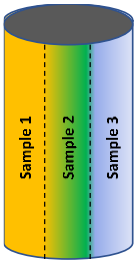

Figure 1: Cylindrical dummy shape for washing using sample 1, sample 2 and sample 3

3 | METHODS

3.1 Washing Methods

For denim washing Tong Yang's industrial washing machine (100 kg), which is a fully automatic washer was used and for

drying purpose Triveneta Granoi Impainti Dryer Machine was used. As mentioned previously, the samples were washed along with other 150 pcs denim. The full process flow and recipe is mentioned in Table 3. As the data were collected from industrial bulk production no concentration was mention in the recipe. The quantity of each chemical type was mentioned as per industrial process.

Table 3: Sequential work process flow for combined enzyme, stone and bleach wash

Process sequence	Process name	Chemical type	Quantity	Time	Temperature
1	Rinse wash	Water	Adequate amount	1 min, 2 times	Room
2	Enzyme stone wash (M: L = 1:8)	Neutral enzyme	700 gm	40 min	45 ℃
3		Anti-back staining	2500 gm		
		Pumice stone	3 bag old + 3 bag new		
	Rinse wash	Water	Adequate amount	1 min, 2 times	Room
4	Only stone wash (M: L = 1:3)	Anti-back stain	2000 gm	15 min	30 ℃
		Pumice stone	1 bag		
5	Rinse wash	Water	Adequate amount	1 min, 2 times	Room
6	Bleach wash (M: L = 1: 10)	Bleaching agent	1500 gm	15 min	50 ℃
		Soda ash	500 gm		
7	Rinse wash	Water	Adequate amount	1 min, 2 times	Room
8	Neutralizing (M: L = 1:3)	Neutralizing agent	1500 gm	5 min	30 ℃
		Anti-back staining	1000 gm		
9	Rinse wash	Water	Adequate amount	1 min, 2 times	Room
10	Neutralizing (M: L = 1:6)	Acid	300 gm	3 min	30 ℃
11	Rinse wash	Water	Adequate amount	1 min, 2 times	Room
12	Hydro extracting			2 min	
13	Drying			15 min	75 ℃

3.2 Testing Methods

To determine the Tensile strength, tearing strength, color fastness to washing, color fastness to rubbing, pH and dimensional stability different standards were used which are listed in Table 4.

Table 4. Evaluation process of washed and unwashed sample

Testing name	Testing standard
Tensile strength	ISO 13934-2:2014
Tearing strength	ISO 13937-1:2000
Color fastness to washing	ISO 105-C06:2010
Color fastness to rubbing	ISO 105-X12:2006
pH	ISO 3071:2020
Dimensional stability	AATCC 150

Tensile strength test was done in accordance with ISO 13934-2:2014 standard using Titan Universal Strength Tester. The tester worked under CRE principle and the sample size was 200 mm x 100 mm. Tearing strength was measured using an Elmendorf Tearing tester which would measure the propagation of tear under standard condition. Color fastness to washing was evaluated by ISO 105-C06:2010 where the staining of color to multifiber fabric would be investigated and rated according to grey scale. Color fastness to rubbing was tested using an automatic crock meter. pH was evaluated using ISO 3071:2020 through digital pH meter. At last, the dimensional stability of fabric was tested by AATCC 150 method where the change in the dimension of fabric before and after washing was measured.

4 | RESULTS AND DISCUSSION

4.1 Appearance and Hand Feel

Due to the wash effect, all the denim fabric samples' appearance changed. The sample also became soft as due to washing action dye and other impurities from the fabrics were removed.

4.2 Tensile and Tearing Strength

The tensile strength value for all three sample is tabulated in Table 5. Tensile strength was measured for both warp and weft way for all the samples. It is visible for the data that after washing the tensile strength values for all the samples were

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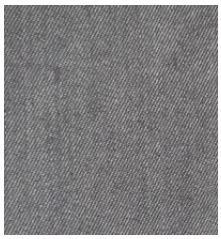

Before wash

After wash

Figure 1: Before and after wash appearance of sample 1

Before wash

After wash

Figure 2: Before and after wash appearance of sample 2

Before wash

After wash

Figure 3: Before and after wash appearance of sample 3

Table 5. Tensile strength values for before and after wash samples

	Before wash			After wash		
Direction	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 1**	**Sample 2**	**Sample 3**
Warp	145 N	139 N	135 N	140 N	105 N	87 N
Weft	85 N	79 N	82 N	58 N	49 N	76 N

Table 6. Tearing strength values for before and after wash samples

	Before wash			After wash		
Direction	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 1**	**Sample 2**	**Sample 3**
Warp	14 N	14 N	13.5 N	10.37 N	9.58 N	10.92 N
Weft	8.5 N	8.2 N	8.5 N	4.58 N	3.60 N	7.12 N

reduced. The reduction of tensile strength value is due to the mechanical abrasion of stones and chemical degradation of enzyme and bleach. Along with the tensile strength, tearing strength was also evaluated and all the samples' tearing strength were also reduced due to the same reason mentioned in Table 6.

4.3 Colorfastness and pH

After any chemical treatment on textile substrate, it should show some sort of color fastness to washing and rubbing. From the data mentioned in Table 7 it is clear that sample 2 and sample 3 showed better washing fastness than sample 1. It happened because the color staining to acetate and acrylic showed rating 4 for sample 1 while other samples showed 4/5 for all kinds of staining. Thus, the samples with higher cotton percentage showed better wash fastness. In case of color fastness to rubbing the after-wash samples showed better resistance because the dye molecules of the fiber surface were extracted by washing abrasion but still not

4.4 GSM and Dimensional Stability

Figure 1 shows that the combined enzyme, stone and bleach wash played significant role and for all samples the GSM reduced after washing. For Sample 2, the GSM reduction was the highest (1.81 oz/yd2). The reduction in GSM was mainly due to the enzyme activity which dissolves the protruding fiber from the surface and mechanical abrasion of stones. The stones and enzymes also bring out some dyes which can also reduce the GSM slightly.

The dimensional stability was checked for all the samples by measuring the warp wise and weft wise shrinkage. It was found that sample 2 showed the highest degree of weft wise shrinkage and sample 1 showed the highest degree of warp wise shrinkage. Weft wise shrinkages were always more than the weft wise shrinkage. The main cause of shrinkage is the absorption of water by cotton yarn. Again, due to the mechanical agitation, the yarns in the fabric become more compact. The main cause of extreme weft wise shrinkage

Table 7: Color fastness to washing (before and after wash)

	Sample 1		Sample 2		Sample 3	
Fastness	**Before wash**	**After wash**	**Before wash**	**After wash**	**Before wash**	**After wash**
Color change	4/5	4/5	4/5	4/5	4/5	4/5
Self-staining	4/5	4/5	4/5	4/5	4/5	4/5
Color staining to acetate	4/5	4	4/5	4/5	4/5	4/5
Color staining to cotton	4/5	4/5	4/5	4/5	4/5	4/5
Color staining to nylon	4/5	4/5	4/5	4/5	4/5	4/5
Color staining to polyester	4/5	4/5	4/5	4/5	4/5	4/5
Color staining to acrylic	4/5	4	4/5	4/5	4/5	4/5
Color staining to wool	4/5	4/5	4/5	4/5	4/5	4/5

Table 8: Color fastness to rubbing (before and after wash)

	Sample 1		Sample 2		Sample 3	
Fastness	**Before wash**	**After wash**	**Before wash**	**After wash**	**Before wash**	**After wash**
Dry crocking	3	4/5	3/4	4/5	3	4/5
Wet crocking	1	1/2	1	2	1	1/2

Before washing the pH of the samples were around 6 but the washing the pH increased a little bit and was found to be around 7 as most of the time the samples were washed under alkaline condition. But the after-wash pH is very much tolerable to body.

could be due to the internal tension of the fabric. In this case it is purely random.

Table 9: pH of before and after wash sample

	Sample 1		Sample 2		Sample 3	
Fastness	**Before wash**	**After wash**	**Before wash**	**After wash**	**Before wash**	**After wash**
pH	6.1	6.8	6.2	7.1	6.3	7.1

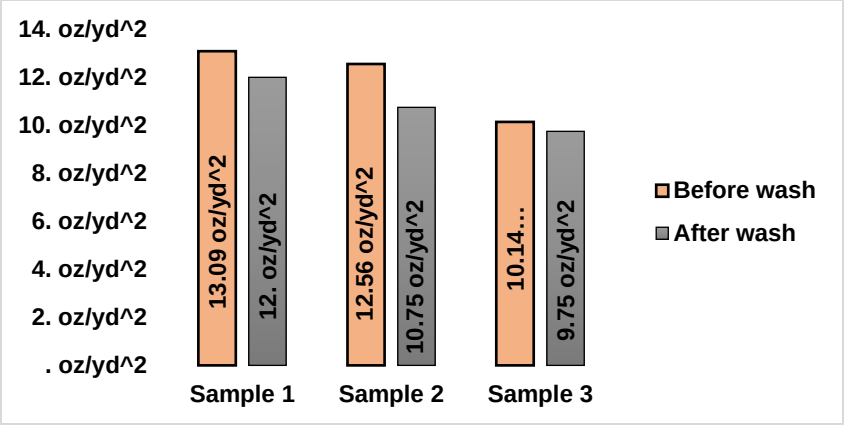

Figure 4: Comparison of GSM of combined enzyme, bleach and stone washed sample

Table 10. Shrinkage test data

		After Wash		
	Original Sample Size (cm)	**Sample 1 (cm)**	**Sample 2 (cm)**	**Sample 3 (cm)**
Warp wise	50.0	49.0	49.5	49.8
Weft wise	50.0	43.4	38.5	47.2

5 | RESULTS AND DISCUSSION

Now-a-days different types of washing is done on the same garment to bring the desired effect because doing a single type of wash on a garment doesn't offer variety to consumers. Again, all types of fabrics are not suitable to combined washing. In this case, tensile strength value for sample 1 (78% BCI Cotton, 20% PIW cotton, 2% Lycra) and sample 2 (88% BCI Cotton, 10% PIW recycled cotton, 2% Lycra) dropped too much in weft way. The same scenario was observed for tearing test also. The color fastness to wet rubbing was not suitable for all the after washed samples in weft direction. In sample 2, the shrinkage effect was the highest. It can be concluded that sample 2 is not suitable for combined enzyme, bleach and stone washing as it has an issue for both chemical and mechanical testing. Most of the testing issues were raised for sample 1 and sample 2 which had the high percentage of recycled cotton. Hence, it can be concluded that for this type of combined washing high percentage of recycled cotton fabric is not suitable because of their lower strength.

REFERENCES

[1] "Characterization and process optimization of indigo dyed cotton denim garments by enzymatic wash | Fashion and Textiles." Accessed: Feb. 27, 2024. [Online]. Available: https://link.springer.com/article/10.1186/s40691-014-0019-0

[2] C. W. Kan, "11 - Washing techniques for denim jeans," in Denim, R. Paul, Ed., in Woodhead Publishing Series in Textiles. , Woodhead Publishing, 2015, pp. 313–356. doi: 10.1016/B978-0-85709-843-6.00011-1.

[3] A. K. R. Choudhury, "3 - Environmental impacts of denim washing," in Sustainability in Denim, S. S. Muthu, Ed., in The Textile Institute Book Series. , Woodhead Publishing, 2017, pp. 49–81. doi: 10.1016/B978-0-08-102043-2.00003-4.

[4] M. J. Hossain, M. S. Hoque, and M. A. Rashid, "Scopes of Acid Washing with Varying Concentrations of Phosphoric Acid vis-à-vis Bleach Wash," Journal of Textile and Apparel, Technology and Management, vol. 11, no. 2, Art. no. 2, Mar. 2020, Accessed: Feb. 27, 2024. [Online]. Available: https://jtatm.textiles.ncsu.edu/index.php/JTATM/article/view/14050

[5] M. Z. Hasan, A. K. M. A. H. Asif, A. Razzaque, M. R. Hasan, S. Sur, and M. O. Faruque, "An Experimental Investigation of Different Washing Processes on Various Properties of Stretch Denim Fabric," Journal of Materials Science and Chemical Engineering, vol. 9, no. 1, Art. no. 1, Jan. 2021, doi: 10.4236/msce.2021.91001.

Declaration of Interests

We, the authors of this research manuscript, declare that we have no financial interest. We have provided written comment to publish the paper in this journal.

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