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A critical review on sustainable enzymatic treatment for denim garments

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Abstract
This project aims with sustainable washing for denim garments by enzymatic treatment. Denim washing is the vital part of finishing process to provide aged look and comfort by reducing the stiffness of garments. It is found that a garments construction is affected largely by washing especially GSM, on the other hand, physical properties in terms of tearing strength. The main objects of washing are to remove size materials to remove starch presents in fabric for soft feeling to wear the garments. The effect of Enzyme is decrease the fabric strength and increases the color fastness and rubbing fastness. A Denim Fabric of twill 2/1 construction was selected for this experiment. Then the Desizing process and then Enzyme wash process was done. Then some Physical and Mechanical tests were taken to compare the differences between the fabric properties before and after Enzyme wash. After Desizing and Enzyme wash. We got GSM, tear strength and Color Rating of the fabric. The tear strength of the fabric are decreased and increased the GSM by increasing time & temperature.

Keywords: denim washing, enzymatic treatment, physical properties, woven fabric, sustainability

Introduction

Denim is the first choice of the current generation when it comes to fashion. This denim dress has become very popular to everyone day by day. The word denim comes from French serge de Nimes, meaning "serge from Nimes". Denim was traditionally colored blue with indigo dye to make blue jeans, although "jean" formerly denoted a different, lighter, cotton fabric .

The most well-known construction configuration in denim is the 3/1 Z twill. In the current creation front view is like 3/1 Z twill sees and the back face is additionally seen as a towel design. Different size materials are used in warp yarn to facilitate weaving.

As a result, the un-washed denim garments are very solid, stiff and rigid, that's why it is necessary to finishing treatment denim garments washing is widely used by this washing process, it appears too attractive, softer, smooth and comfortable, comes to good wear performance which easily attracts the buyer towards the denim for its extraordinary look. The durability of denim is also observed more than other garments [4, 5]. Most regular denim washing process is enzyme wash, stone wash, bleach wash, acid wash, Normal wash, PP spray, etc. among this enzymatic method is a widely used method in the industry . But this denim wash requires a huge amount of water, which is a matter of great concern for the future. We should need to think now about how to do sustainable washing, in this study we will discuss how to do enzyme washing more sustainable. Enzymes are protein, composed of amino-acids, which are produced by all living organisms. Enzymes are responsible for a number of reaction and biological activities. It is also biocatalysts and organic compound of higher atomic weight. They are very specific about their work. Most of the enzymes slightly break down color bond of fabric and highly breakdown soils and stains from the surfaces. Finally using enzymes in denim washing provides a gorgeous shade look in the fabric [7, 8].

In this study, showed a complete analysis of sustainable enzyme washing in denim fabric and how the denim fabric properties were changed due to enzyme washing.

Materials and Methods

Materials

- Fabric Category : Denim (indigo)
- Composition: 100% cotton,
- Fabric Type: 2/1 ‘Z’ Twill
- GSM: 407
- Construction: 76/44
- EPI: 76
- PPI: 44
- Warp Count: 7
- Weft Count: 7

Chemicals and Auxiliaries

- Enzyme (nova stone combi-new): 2%
- Anti-back staining agent: 0.5 g/l
- Detergent (Kohinoor, BD): 0.6g/l
- Biological detergent as desizing agent, Germany: 0.6%
- Soda ash (Nirma, India):1.2g/l
- Acetic acid (China): 1g/l
- Textsoft softener (Germany): 1g/l

Equipment

- Garments Washing Machine (Front loading)
- Chemical Mixture Machine
- Hydro Extractor Machine
- Dryer Machine(Steam)
- Tensile Strength Machine
- GSM Cutter
- Crock meter

Machine Used for Washing and Drying

- Front Loading Washing Machine
- Chemical Mixture M/C

Machine Used For Testing

- Crock meter/Rubbing fastness test

- Tear testing machine
- Counting Glass

Methods

Fabric Preparation

At first we collected Indigo dyed denim fabric from market and layout the fabric on table. Putted a trouser pattern on the fabric and cut the fabric as per pattern then sewing them by chain stitch machine.

Desizing Treatment

Recipe

- Soda ash: 1.2 g/l
- Detergent: 0.6 g/l
- Desizing agent: 0.6 g/l
- Material to liquor ratio 1:30
- Temperature: 60°C
- Time: 20 min.

Denim trousers were desized using detergent, desizing agent and soda ash. This treatment was conducted in liquor containing above chemical and material to liquor ratio of 1:30 in a laboratory sample washing machine at 60°C for 20 min. The garments were then washed with hot water (70°C) & Drain. Again we took cold water in the washing m/c for Variable Enzyme treatment process such as 0.5 to 3.5%.

Enzyme (Cellulose) Treatment

Recipe

- Enzyme Nova stone combi new: 2%
- Acetic acid: 1g/l
- PH: 5.5
- Temperature: 40 - 55°C
- Time: 20 - 55 min

De-sized trousers were treated using cellulose enzyme. This process was conducted in liquor containing acetic acid (1g/l) at P^H 4.5-5.5 and material to liquor ratio of 1:30. The enzyme treatment was carried out at 2% (Fixed) and temperatures variable (40°C, 45°C, 50°C, 55°C) and treatment time (30 min). After desired time the temperature was raised to 90°C for 1 min to stop enzyme action. The denim garments were then washed with hot water then washed with cold water [9].

Softening

Finally, garments were softened with Textsoft softener (1 g/l) at 40°C for 10 min.

Drying Processes

After treatment, the washed denim trousers were squeezed in a laboratory scale hydro-extractor machine (Zanussi, Roaches, England) at 200 rpm for 3-4 min to remove excess water and then dried in a steam drier (Opti-Dry, Roaches, England) at 75°C for 35-40 min. Treated denim garments were then evaluated in testing machines and characterized of their physical and mechanical properties to determine product performance [10].

Testing and Analysis

- Treated all denim trousers were conditioned at 65% RH and at 20°C for 24 h before testing according to BS EN ISO 139:2005 and ASTM D1776.
- Tear strength was determined by the US Standard Grab test method according to ASTM D2261.
- Weight loss (%) in fabric was calculated from the difference in fabric weight (GSM) before and after the treatment according to ASTM D3776.
- Change in the original color shade of the fabric was rated using gray scale for color change according to AATCC test method 61.
- Rubbing fastness of samples were evaluated by crock meter machine according to ISO 105E12 standard.
- EPI and PPI were measured manually by using needle and counting glass.
- Enzymatic effects were observed visually [11].

Table 1: Experiment design analysis based on variable temperature

Temp. (°C)	Enzyme conc.%	Time (Min)
40	2	30
45		
50		
55		

In the above table 1 this experimental single factor analysis we assume the variable temperature from 40°C to 55°C and time for 30 minute and enzyme concentration 2%. After completing the process we found the visual analysis suitable temperature at 50°C [12].

Table 2: Experiment design analysis based on variable Temperature.

Enzyme conc.%	Variable Time (Min)	Temp. (°C)
2	20	50°C
	25	
	30	
	35	

From the above table 2 we know enzyme concentration 2%, and variable time 20-35 minutes and suitable temperature at 50°C.

Table 3: Suitable results comparing the Table 1 and Table 2

Enzyme conc.%	Suitable Temp. (°C)	Suitable Time (Min)
2	50	30

Finally, from table 3, we got the suitable time for 30 minutes and suitable temperature 50°C and fixed enzyme concentration 2%.

Results and Discussion

Experimental Analysis

GSM analysis

Table 4: GSM Test in Variable Temperature

Fabric Sample	GSM	Variable Temp. (°C)	Time (Min	Enzyme concentration (%)
Before Wash	407		30	2
S1	420	40		
S2	424	45		
S3	428	50		
S4	433	55		

In the above table 4, this experimental single factor analysis we assume the variable temperature from 40°C to 55°C and time for 30 minute and enzyme concentration 2%. After completing the process we found the GSM variation for

variable temperature. It is observed that GSM is increased with the increment of temperature [13].

Table 5: GSM Test in Variable Time

Fabric Sample	GSM	Variable Time (Min)	Temp. (°C)	Enzyme concentration (%)
Before Wash	407		50	2
S1	423	20		
S2	427	25		
S3	430	30		
S4	436	35		

In the above table 5, this experimental single factor analysis we assume the variable time from 20min to 35min and temperature for 50˚C and fixed enzyme concentration 2%. After completing the process we found the GSM variation for variable time. It is observed that GSM is also increased with the increment of time [14].

Wet rubbing test

Table 6: Wet rubbing test in Variable Temperature

Fabric Sample	Rating	Variable Temp. (°C)	Time (Min)	Enzyme concentration (%)
Before Wash	2		30	2
S1	3	40		
S2	3	45		
S3	3	50		
S4	3	55		

In the above table 6, this experimental single factor analysis we assume the variable temperature from 40°C to 55°C and time for 30 minute and enzyme concentration 2%. After completing the process we found the Wet Rubbing remained same for variable temperature [15].

Table 7: Wet rubbing test in Variable Time

Fabric Sample	Rating	Variable Time (Min)	Temp. (°C)	Enzyme concentration (%)
Before Wash	2			
S1	3	20	50	2
S2	3	25	50	2
S3	3	30	50	2
S4	3	35	50	2

In the above table 7, this experimental single factor analysis we assume the variable time from 20min to 35min and temperature for 50˚C and fixed enzyme concentration 2%. After completing the process we found the Wet Rubbing is also remained same for variable time [16].

Dry rubbing test

Table 8: Dry rubbing test in Variable Temperature

Fabric Sample	Rating	Variable Temp. (°C)	Time (Min)	Enzyme concentration (%)
Before Wash	2		30	2
S1	3	40		
S2	3	45		
S3	3	50		
S4	3	55		

In the above table 8, this experimental single factor analysis we assume the variable temperature from 40°C to 55°C and time for 30 minute and enzyme concentration 2%. After completing the process we found the Dry Rubbing remained same for variable temperature.

Table 9: Dry rubbing test in Variable Time

Fabric Sample	Rating	Variable Tem. (°C)	Tim (Min)	Enzyme concentration (%)
Before Wash	2		50	2
S1	3	20		
S2	3	25		
S3	3	30		
S4	3	35		

In the above table 9, this experimental single factor analysis we assume the variable time from 20min to 35min and temperature for 50˚C and fixed enzyme concentration 2%.After completing the process we found the Dry Rubbing remained same for variable time.

Table 10: Shrinkage test in Variable Temperature

Fabric Sample	Percentage (%)	Variable Temp. (°C)	Time min.	Enzyme concentration (%)
Before wash	5%		30	2
S1	6%	40		
S2	7%	45		
S3	7%	50		
S4	8%	55		

In the above table 10, this experimental single factor analysis we assume the variable temperature from 40°C to 55°C and time for 30 minute and enzyme concentration 2%. After completing the process we found the Shrinkage (%) variation for variable temperature. It is observed that Shrinkage (%) is increased with the increment of temperature [17].

Table 11: Shrinkage test in variable time

Fabric Sample	Percentage (%)	Variable Temp. (°C)	Time min.	Enzyme concentration (%)
Before wash	5%		50	2
S1	6%	20		
S2	7%	25		
S3	7%	30		
S4	7%	35		

In the above table 11, this experimental single factor analysis we assume the variable time from 20min to 35min and temperature for 50°C and fixed enzyme concentration 2%. After completing the process we found the Shrinkage (%) variation for variable temperature. It is observed that Shrinkage (%) is increased with the increment of time.

Tear strength test

Table 12: Tear strength test in variable temperature

Fabric Sample	Strength	Variable Temperature (°C)	Time min.	Enzyme concentration (%)
Before wash	Warp wise=2221kg Weft wise=1753kg		30	2
S1	Warp wise=1920kg Weft wise=1728kg	40		
S2	Warp wise=1903kg Weft wise=1684kg	45		
S3	Warp wise=1856kg Weft wise=1656kg	50		
S4	Warp wise=1700kg Weft wise=1603kg	55		

In the above table 12, this experimental single factor analysis we assume the variable temperature from 40°C to 55°C and time for 30 minute and enzyme concentration 2%. After completing the process we found the Tear Strength variation for variable temperature. It is observed that Tear Strength is increased with the increment of temperature [18].

Table 13: Tear strength test in variable time

Fabric Sample	Strength	Variable Temperature (°C)	Time min.	Enzyme concentration (%)
Before Wash	Warp wise=2221kg Weft wise=1753kg		50	2
S1	Warp wise=1920kg Weft wise=1728kg	20		
S2	Warp wise=1903kg Weft wise=1684kg	25		
S3	Warp wise=1856kg Weft wise=1656kg	30		
S4	Warp wise=1700kg Weft wise=1603kg	35		

In the above table 13, from this experimental single factor analysis we assume the variable time from 20min to 35min and temperature for 50°C and fixed enzyme concentration 2%. After completing the process we found the Tear Strength variation for variable temperature. It is observed that Tear Strength is increased with the increment of time.

Temperature of cellulose enzyme treatment

The effect of cellulose in denim garment washing under the influence of 40, 45, 50°C for 30-40 min was investigated. The effect of temperature on loss in tensile strength, color fading, fabric weight, is shown in Table (Taguchi Analysis: Tensile strength warp, weft, GSM, color rating). Temperature of washing treatment specifically between 55 and 65°C decrease the color shade remarkable what we had done in Single Factor Experiment Design; higher temperature, i.e. 70°C does not cause further decrease in color shade, because the action of enzyme decreased at higher temperature.

The effect of temperature on surface roughness is clear particularly when enzyme wash was performed at 55°C–60°C. It is selected that 40-45°C washing temperature is optimum for denim washing with cellulose enzyme [19].

Time of cellulose enzyme treatment

The effect of time on denim fabric properties is shown in Table (Taguchi Analysis: Tensile strength warp, weft, GSM, color rating). It effects on fabric strength, color fading, softness, shrinkage and GSM. So considering strength, softness, shrinkage, it is selected that 30-35 min washing time is optimum for denim washing with cellulose enzyme.

Conclusions

The tear strength, shrinkage and color shade decrease after cellulose enzyme washing treatment; meanwhile fabric GSM obtained little bit higher than those of prewashing due to more shrinkage in warp direction. It is further noted that pre-washed denim samples are almost stiff and harder than the enzyme treated cotton denim garments.

Conflict of Interest

None.

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