Standardisation of Bioscouring Enzyme for Sustainable Cotton Fabric Treatment

ABSTRACT

Bioscouring is an advanced enzymatic method for treating cotton fabrics, effectively removing impurities and enhancing fabric properties. This study compares traditional chemical scouring with bioscouring, evaluating their efficiency in terms of absorbency, sinking, and capillary rise tests. The results demonstrate the potential of bioscouring in improving fabric porosity, absorbency, and hydrophilicity while maintaining excellent wash fastness and dyeing properties. By optimising the concentration of bioscouring enzymes, this research contributes to reducing the environmental impact of textile manufacturing while maintaining or improving fabric quality.

INTRODUCTION

Cotton fabric scouring is a critical pretreatment process in textile manufacturing, essential for removing natural waxes, non-fibrous impurities, and additional soiling or dirt from the fabrics. Traditionally, this process involves the application of strong alkaline solutions, commonly sodium hydroxide (NaOH), at elevated temperatures (approximately 89°C). These treatments saponify waxes and oils and solubilize pectins and other non-cellulosic materials, effectively cleaning the fabric. This method, typically performed in kiers, consumes vast amounts of water and energy, generating significant wastewater and chemical pollution.

The textile industry is one of the largest consumers of water, requiring approximately 200 litres of fresh water to finish 1 kg of textile fabric, leading to substantial wastewater production. Given the environmental concerns associated with conventional scouring, sustainable alternatives such as bioscouring have been developed. Bioscouring employs enzymes like pectinase, which specifically target and remove pectin, a major non-cellulosic impurity in cotton fibres, without damaging the cellulose structure.

Many traditional finishing processes in the textile industry can be replaced by sustainable, environmentally friendly, biotechnological processes through the use of enzymes such as amylase, cellulase, laccase, and pectinase. These environmentally friendly processes conserve vast amounts of water, energy, chemicals, and textile auxiliaries, significantly reducing the environmental footprint of textile manufacturing.

The pretreatment of cotton aims to eliminate natural fibre components and remove sizes applied on the warp before weaving to achieve good absorbency and a high level of desizing. This is usually done in three steps:

Desizing: Necessary process for removing sizing agents from woven fabrics.

Alkaline Scouring: Applied to remove natural substances such as pectins, fats, and waxes from the fibre, achieving good hydrophilic properties.

Bleaching: Performed to obtain a high degree of whiteness and remove vegetable impurities.

These traditional processes require large amounts of caustic soda and textile auxiliaries. Furthermore, the alkali used must be subsequently neutralised, adding to the chemical load. This study aims to optimise the concentration of bioscouring enzymes and compare the efficacy and environmental impact of bioscouring with conventional scouring methods. By exploring sustainable alternatives, this research contributes to the ongoing efforts to reduce the environmental impact of textile manufacturing while maintaining or improving fabric quality.

BIOSCOURING

The caustic flakes neutralise acidic materials, saponify glycerides (waxes and oils), and solubilize silicates. The wetting agent reduces surface tension and minimises interfacial tensions. Detergents emulsify fats, oils, and waxes; remove oil-borne stains; and suspend materials after they have been removed. Chelating (sequestering agents) deactivate metal ions. Builders (salt) enhance detergent effectiveness. Solvents assist emulsification by dissolving oily materials.

METHODOLOGY

Conventional scouring:
100% cotton greige hosiery material was used for the scouring process. The process involved using caustic flakes (2%), hydrogen peroxide (3%), Kleenox Knitz Liquid (0.83%), and Zyastab REV Liquid (0.3%). The fabric was treated at 98℃ for 45 minutes in a Rota dyer with a material-to-liquor ratio of 1:10. This was followed by hot washing, cold washing, and neutralization. Residual peroxide was removed using Ultrox RJK Liquid (0.50%) at 55℃ for 10 minutes, followed by a cold wash.

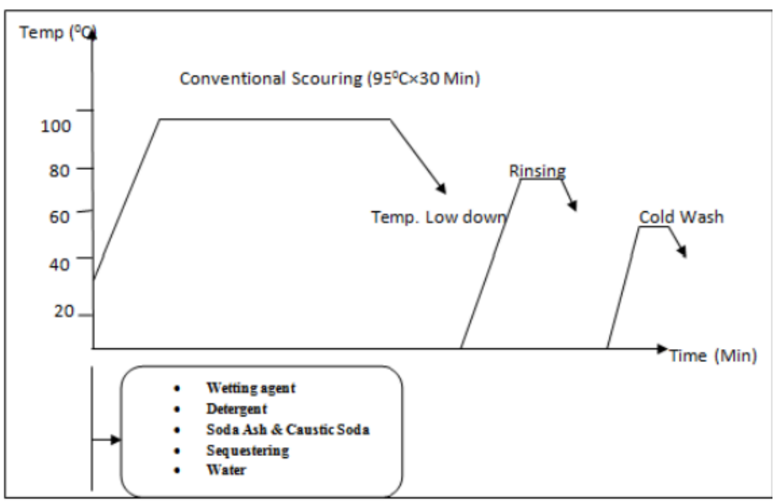

Figure 1: conventional scouring curve

Bioscouring
100% cotton greige hosiery material was treated with Greenboost Liquid (1%) and Kleenox Knitz Liquid (0.80%). The fabric was treated at 60℃ for 20 minutes in a Rota dyer with a material-to-liquor ratio of 1:10. The temperature of the same bath was raised to 85℃ and further treated for 20 minutes, followed by a hot wash.

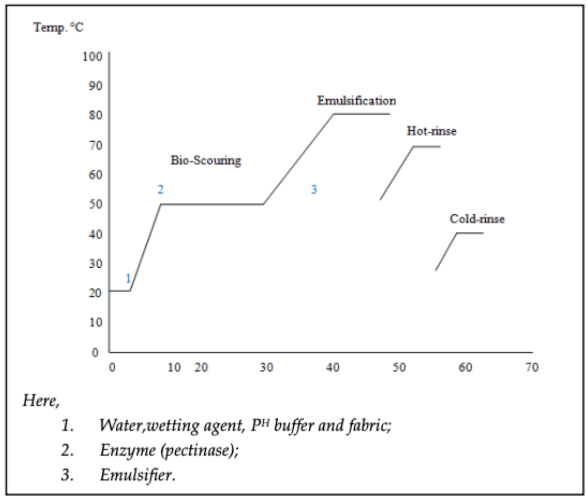

Figure 2: Bioscouring curve

Dyeing:

Dyeing was carried out using reactive dyes Rosa G. Yellow MER (0.03%), Rosa Red ME 4B HIC (0.05%), and Rosa Blue ME2R (0.005%). Common salt (25g/L) and soda ash (12g/L) were used for exhaustion and fixation steps in dyeing. Additionally, 20 mL of water was also added. First, salt was added and ran for 30 minutes at 60℃, followed by soda ash addition with a 60-minute running time at 60℃. Cold wash and hot wash were carried out after dyeing, followed by neutralisation. Soaping was done using Zycol PRSK Liquid (2g/L).

Absorbency, Sinking, and Capillary Tests

Absorbency was measured using the drop test, where the time taken for a water drop to be absorbed by the fabric was recorded. Sinking tests evaluated the time for the fabric to sink in water, and capillary rise tests measured the height water reached through capillary action.

Recipe Optimization

Different percentages of Green Boost Liquid (enzyme) were tested with a wetting agent (Biowet). The fabrics were treated at 60°C for 45 minutes in a Rota dyer with a material-to-liquor ratio of 1:10. This was followed by a cold wash, then the temperature was raised to 85°C for 20 minutes, during which a hot wash was conducted.

Details	Recipe 1	Recipe 2	Recipe 3	Recipe 4	Recipe 5	Recipe 6	Recipe 7	Recipe 8
Greenboost enzyme	0.1%	0.2%	0.3%	0.5%	0.7%	0.8%	1.0%	1.2%
Biowet (wetting agent)	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%

This table outlines the optimization of enzyme concentrations for effective bioscouring. The varying enzyme concentrations allow for the assessment of the optimal amount required to achieve the best cleaning and fabric strength without compromising the environmental benefits.

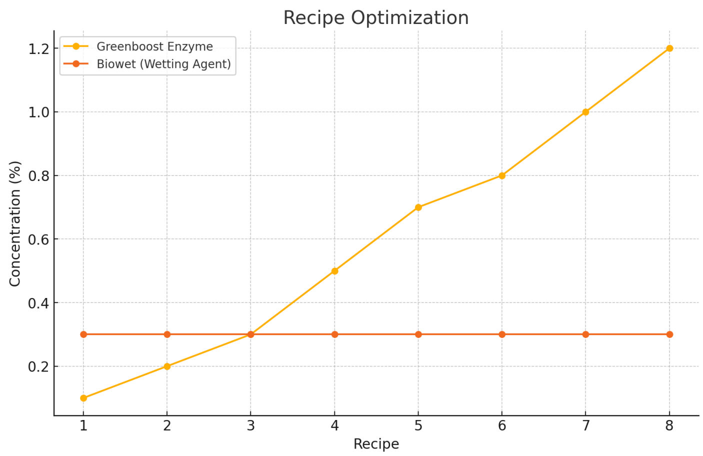

Figure 3: Recipe

Details	**Absorbency**				**Sinking**				**Capillary**
	1	2	3	**Mean**	1	2	3	**Mean**	1
conventional									
conventional	4	6	5	**5**	4	5	6	**5**	3.6
bioscouring									
Recipe 1	30	27	22	**26**	32	42	33	**35**	0.6
Recipe 2	19	22	19	**20**	24	26	22	**24**	0.9
Recipe 3	18	15	17	**17**	21	21	24	**22**	1
Recipe 4	15	14	17	**15**	22	23	21	**22**	1.5
Recipe 5	11	16	12	**13**	13	15	15	**14**	1.8
Recipe 6	11	13	14	**12**	13	12	13	**12**	2.1
Recipe 7	9	6	5	**6**	10	11	12	**11**	2.1
Recipe 8	3	4	7	**4**	8	9	6	**7**	2.3

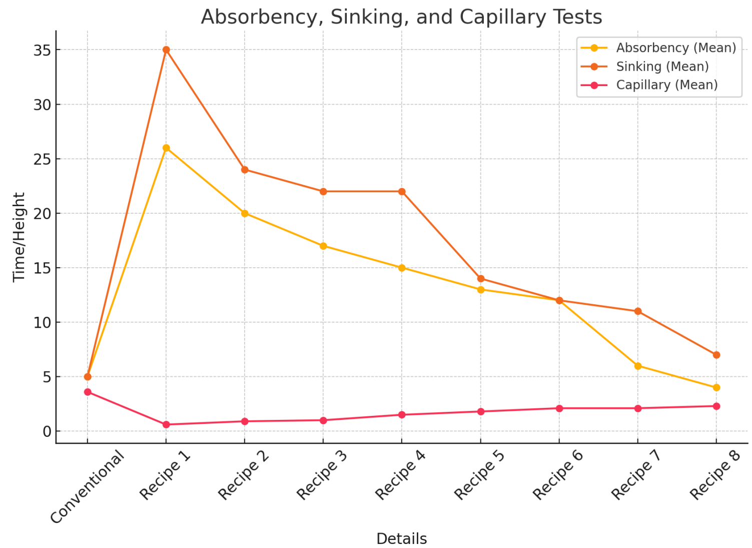

Figure 4: Results of the absorbency, sinking and capillary test

Absorbency Test

The absorbency test measures how quickly water can penetrate and be absorbed by the fabric, with a lower mean absorbency time indicating better water uptake. The test results showed that the mean absorbency time for conventionally scoured fabrics was 5, while for bioscoured fabrics it was 26. This suggests that only the highest concentration of enzymes in the bio process provided a marginally better absorbency result compared to the conventional scouring method.

Figure 5: absorbency test

Sinking Test

The statement that bioscoured fabrics sink much faster than conventionally scoured ones, confirming their improved hydrophilicity, needs clarification. While the data shows that conventionally scoured fabrics have a slightly better wettability with a shorter average sinking time of 5 seconds compared to 7 seconds for bioscoured fabrics at the highest enzyme dosage level, bioscouring still demonstrates effective hydrophilicity. The bioscouring process, even though it shows a marginally longer sinking time, effectively enhances the fabric's overall absorbency and environmental sustainability by using enzymes instead of harsher chemicals.

Capillary Rise Test

The capillary rise test measures the height to which water rises in the fabric due to capillary action, with a higher capillary rise indicating better fabric porosity and wicking properties. The results showed that conventional fabrics had a higher capillary rise of 3.6 inches, compared to 2.3 inches for bioscoured fabrics at the highest enzyme dosage level.

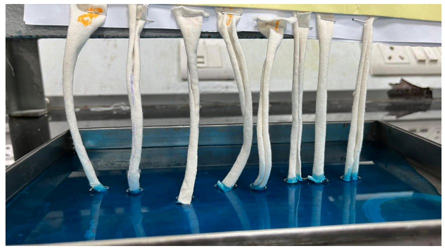

Figure 6: Capillary test

Table: Colorimetric Values for Conventional and Bioscoured Fabrics as measured by a spectrophotometer

CONVENTIONAL

	L*	a*	b*	c*	h°
	70.15	22.00	4.10	22.38	10.55

BIOSCOURED

	DL*	Da*	Db*	DC*	DH*	DE*	%STR-WSUM	%STR-SWL
1	-0.94 D	-0.68G	1.51 Y	-0.34 D	1.62 Y	1.90	110.87	105.70
2	-1.20 D	-2.42G	1.12 Y	-2.11 D	1.62 Y	2.92	111.24	104.53
3	-3.04 D	-11.86 G	-3.66 B	-12.23 D	-2.12 B	12.77	114.80	99.26
4	-2.17 D	0.30 R	1.16 Y	0.54 B	1.07 Y	2.48	121.72	118.19
5	-0.26 D	-5.27 G	0.06 Y	-5.14 D	1.16 Y	5.27	99.93	92.28
6	-3.28 D	-13.07 G	-3.93 B	-13.45 D	-2.34 B	14.04	116.56	98.44
7	-0.76 D	-3.20 G	0.09 Y	-3.12 D	-0.73 Y	3.29	104.85	99.70
8	-0.84 D	-0.93 G	1.45 Y	-0.59 D	1.62 Y	1.91	109.66	104.86

Colorimetric analysis shows the differences in colour properties between conventionally scoured and bioscoured fabrics. The DL*, Da*, Db*, DC*, and DH* values represent changes in lightness, red-green, yellow-blue, chroma, and hue, respectively. The data indicates that bioscouring can slightly alter the colour properties of the fabric, which may affect the dyeing outcomes.

100% cotton greige hosiery material was used for the dyeing process. The process involved using non-ionic detergent (3 g/l), and soda ash (2 g/l). The fabric was treated at 60℃ for 30 minutes in a Rota dyer with a material-to-liquor ratio of 1:50. This was followed by draining and then a rinse and dry. The staining of the fabric on the multi fibre strip was then tested.

Wash fastness:

Details	Staining on multi fibre strip					
	Acetate	**Cotton**	**Nylon**	**Polyester**	**Acrylic**	**Wool**
Conventional						
conventional	4-5	4	4-5	4-5	4-5	4-5
Bioscoured						
bioscoured	4-5	4-5	4-5	4-5	4-5	4-5

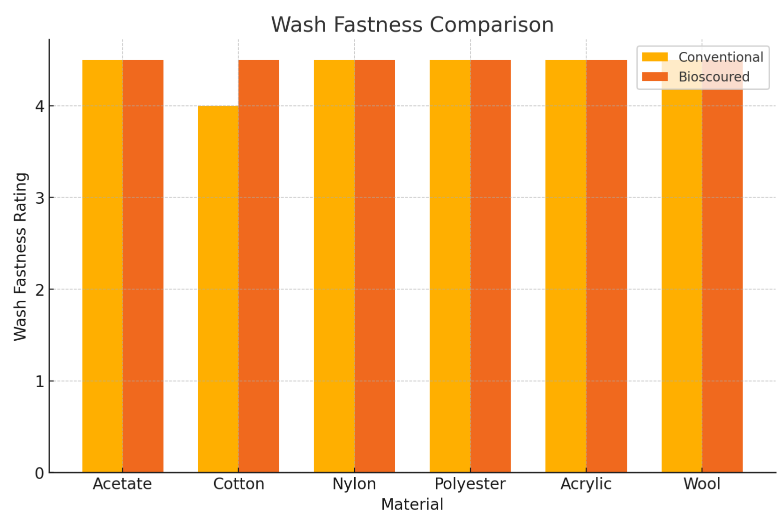

Figure 7: Comparison of wash fastness on a multi-fibre strip

Wash fastness measures the resistance of dyed fabrics to washing. The test assesses staining on different fibre types. Both conventional and bioscoured fabrics show excellent wash fastness, indicating that bioscouring does not negatively affect the fabric's ability to retain dyes during washing.

RESULTS

	Bioscouring	Traditional scouring
Temperature Since 1℃ rise in temperature takes one minute, the amount of time saved	60℃	98℃ Traditional scouring processes use high temperatures to effectively

by bioscouring: 38 minutes	Bioscouring operates efficiently at lower temperatures, saving energy and reducing processing time.	remove impurities and achieve desired fabric cleanliness.
Neutralisation process	Eliminates the need for a neutralisation process. Bioscouring uses enzymes that do not require neutralisation, simplifying the process and reducing chemical usage and saving one bath.	Requires a neutralisation process. The alkali used in traditional scouring needs to be neutralised to prevent damage to the fabric and to reduce environmental impact.
Effect on the environment	Uses pectin lyases and pectate lyases or transaminases, reducing water and energy usage and lowering the chemical oxygen demand (COD) and biological oxygen demand (BOD) in wastewater. Enzymatic processes are more targeted and efficient, resulting in fewer pollutants and lower environmental impact.	Generates significant heat and oxygen, contributing to the factory's total pollution load. Uses caustic flakes and hydrogen peroxide. Traditional scouring involves chemical reactions that produce pollutants, requiring extensive water and energy resources. 10- 20% of the total pollution load generated during the entire textile processing operation.
Effect on output	It does not destroy the cellulose structure and hence prevents the loss of cellulose weight and strength.	Air permeability, tearing strength, bursting strength and the elongation of the fabric changes.
Fabric strength	Targets the primary cell wall of fibres, increasing fabric strength and enhancing dye absorption. Bioscouring enzymes selectively remove impurities without harming the cellulose structure, preserving fabric strength.	Attacks both primary and secondary cell walls, causing significant strength damage. The harsh chemicals used in traditional scouring can weaken the fabric by damaging its structural integrity.
Dye loss Higher removal of pectin causes higher space in the fibres for dyestuff penetration, reaction and fixation.	Requires less dye-stuff. Bioscouring improves the fabric's porosity and dye absorption capacity, allowing for more efficient dyeing with less dye-stuff.	Requires a higher amount of dye-stuff. Traditional scouring does not prepare the fabric as effectively for dye uptake, necessitating more dye-stuff to achieve the desired colour.
Cost	More expensive. The initial cost of enzymes and the specialised process can be higher, although long-term savings and environmental benefits may offset this.	Generally cost-effective. The chemicals and processes used in traditional scouring are often less expensive in the short term.
Risk assessments	Avoids the use of harsh chemicals, lowering the risk of dangerous	Involves handling harsh chemicals, increasing the possibility of accidents

	accidents and health hazards for workers. Enzymatic scouring is safer and less hazardous, reducing the potential for workplace accidents and long-term health issues for workers.	and health hazards. The use of strong alkalis and oxidizers poses risks to workers and requires careful handling and safety measures.

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