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Research Article

A novel approach to sustainable denim wash: study on effect of low water ratio bio-washing on denim fabric shade

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Abstract

In comparison to other manufacturing industries, the textile denim business has a very high water footprint. We develop a unique washing recipe within acceptable shades to provide a sustainable washing technique that will limit the wasteful consumption of water. We investigated bio-polish and bio-magic enzyme on three types of fabric samples and discovered that bio-magic uses very little water as bio-polish while producing a shade that is identical to bio-polish. We do mechanical tests and observe that after bio-magic treatment, all fabrics lose a disproportionate amount of weight and have a significant loss of tear and tensile strength. This is owing to the fact that simultaneous enzymatic and mechanical action happens within the machine during bio-magic treatment. Colorfastness to crocking, dimensional stability to washing and skewness are all taken into consideration. Denim fabric washed with bio-magic: a neutral lipase enzyme based on Humicola presents long-term possibilities for the denim business.

Keywords: *Climate change, sustainable washing, bio-magic, bio-polish, water footprint, textile industry*

Introduction

Seas and oceans contain the majority of the world's water. However, due to its salinity, their water is unfit for human consumption, agriculture, or manufacturing usage. Source of surface water are rivers, lakes, and aquifers. But these sources are limited. Water is essential for human living; without it, we would perish. To be healthy, an average person needs to drink roughly 2.5 liters of water every day. Water is required for the survival of cattle and the growth of plants. Without water, obviously, no food can be grown. Human can use less than 1% of the freshwater available on the earth [1]. Long-term economic growth, public health, social assistance, and ecological sustainability all require water. Water does, after all, penetrate all social activity.

Shiklomanov (1998) calculated historical water withdrawals, usage, and predictions for 2025 [2]. It's worth noting that worldwide withdrawals in 2025 are expected to be approximately ten times higher than they were in 1900. Withdrawals and usage are growing at different rates around the world, as one might expect. The term "water crisis" refers to a general scarcity of usable water in comparison to the need of society to satisfy residential requirements, cultivate agricultural, run factories, create electricity, keep the environment clean, and so forth.

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According to various statistical reports, around 1.1 billion people don't have clean water for drinking and 2.4 billion lack healthy sanitation facilities [3-5].

Until recently, there was little information available on the global annual output of organic dyes. However, there are over 100,000 different types of commercially accessible dyes, with a yearly global production of 700,000–1,000,000 tons documented in the research [6]. 90% of all dyes manufactured are expected to wind up in fabrics, with the remainder going to the leather, paper, plastics, and chemical industries [7]. Annually, 280 000 tons of textile dyes are expected to be emitted as industrial wastewater around the world [8]. As per new analysis by [9] a Cleveland-based consultancy organization, the Asia-Pacific region will dominate production and boost its market share to almost 50% of global demand by 2013. From 1.9 million tons in 2008 to 2.3 million tons in 2013, global consumption of dyes and pigments is predicted to grow at a 3.5% annual rate.

China's textile exports have recently surpassed the $274 billion threshold, exceeding [10]. Although becoming a huge source of revenue, this business has become a significant source of pollution around the world, posing adverse effects on the environment. Textile products are treated with a variety of toxic chemicals in wet textile manufacturing, including dyestuffs, finishing agents, and other associated auxiliaries. Unfixed dyes and other chemicals are later released as industrial effluent, polluting the environment and posing major health risks to humans [11].

Currently, multiple strategies are being formulated to achieve sustainable technology using green chemistry principles[12]. Researches have been made to design textile processing methodologies which yield zero or least amount of waste. Recent developments in the field of sustainable textiles have optimized dyeing and printing operations with inclusion of recycled and greener chemicals [13-15].

Varsha Panwar et al. [16] studied on sustainable technology of denim bleaching. Their study was based on thermostable bacterial laccase. They isolated a high molecular weight (88 kDa) extremophilic laccase (LacT) from Brevibacillus agri. Their aim was to make use of its extreme characters in denim bleaching. LacT showed greater efficacy to hazardous azo dyes used in the bleaching of denim. This technology is promising in the area of bio bleaching.

Tammy M Hsu et al. formulated a sustainable indigo dyeing strategy based on biochemical protecting group [17]. The biochemical protecting group is a glucose moiety. This strategy stabilizes the reactive indigo precursor indoxyl to form indicant that prevent spontaneous oxidation to crystalline indigo during microbial fermentation.

Fatma Sener Fidan et al. [18] researched on indigo rope dyeing considering multi dimension of sustainability. Their study was based on life cycle approach and hesitant fuzzy analytic hierarchy process (HF-AHP). A new recipe was formulated to assess the sustainability of indigo rope dyeing. According to their study, the most important criteria in assessing the sustainability of denim production was environmental impact (33%). The second most important criteria was social impacts with (27%). The rests are quality results (23%) and economic results (17%). These results indicate that the sustainability of the indigo rope dyeing process could be improved by using chemicals and dyestuff that are manufactured by green technology.

V. Buscio et al. [19] studied sustainable dyeing of denim using indigo dye recovered with polyvinylidene difluoride ultrafiltration membranes. In this work, real effluents that contained indigo dye were treated by means of 4 different ultrafiltration membranes. Fabrics dyed with the recovered indigo concentrates exhibited similar characteristics than the ones obtained with the commercial dye.

Xiaoyan Li et al. [20] worked on sustainable electrochemical dyeing of indigo with Fe (II)-based complexes. The eco-friendly electrochemical dyeing strategy presented here with obvious economic benefits could significantly contribute to enhance the sustainability of dyeing process for denim production.

To produce 60 billion kilograms of fabric approximately 1 trillion kilowatt of electricity and 9 trillion liters of water are required[21]. In developing and developed countries meeting human needs would require reuse and decentralization. One such technology is the Membrane Bioreactor (MBR) which is a combination of biological sludge process and micro or ultrafiltration membrane system[22].

Aim of this study was to limit the use of water in textile wet processing to minimize water footprint in textile industry. In this paper the authors have developed a method to compare it with the traditional wet process. The developed method has efficacy of using less water hence it is termed “bio-magic”.

Experimental

Sample preparation

Woven denim fabrics were used for the study. Three types of denim fabrics were used with different fiber contents. They are 100% Cotton (mid indigo) - F1, 98% Cotton/2% Elastane (dark indigo) - F2, 79% Cotton/11% Polyester/9% Hemp/1% Elastane (charcoal black) - F3. Each fabric sample length was 1.5 yds with varying fabric width for different fabric types. Then samples were washed with two different washing procedures- Bio-polish and Bio-magic or aqua less wash. In this study, our aim is to reduce the consumption of washing water considerably. Separate washing recipe was developed for these two method. We used Garments washing machine to apply the desired shade and effect on denim fabrics. The recipe we had utilized in washing along with different chemicals, dosage, temperature, time and water consumption are in the below tables. After washing, we dried the fabric samples and then performed different characterization processes to evaluate the validity of our research work.

Table 1: Specifications of sample fabrics

Fabric Specification	F1	F2	F3
Fiber Content	100% Cotton	98% Cotton + 2% Elastane	79% Cotton +11% Polyester +9% Hemp +1% Elastane
Weave Type	3/1 RH Twill	3/1 RH Twill	3/1 RH Twill
Warp Count (Ne)	10 Carded	13 Carded	10 Ring slub
Weft Count (Ne)	9 Carded	5.8 Carded	7 Ring slub
Ends per inch (EPI)	77	80	84
Picks per inch (PPI)	58	56	62
Fabric width (Inch)	60”	57”	56”
GSM	328	372	405
Shade type	Mid Indigo	Charcoal Black	Dark Indigo

Table 2: Bio-polish and Bio-magic enzyme for denim washing

Enzyme	Description
Bio-polish enzyme	*Trichoderma* based enzyme: cellulase, acid enzyme, liquid form
Bio-magic enzyme	*Humicola* based enzyme: lipase, neutral enzyme, powder form

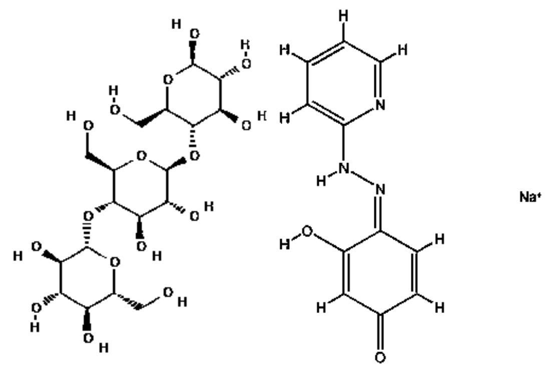

Figure 1: Cellulase and lipase chemical structure

Table 3: Bio-polish washing recipe

S.N	Process name	Liquor ratio	Water (liters)	Time (min)	Temp (˚c)	pH	Chemical name	Dosage
1	Desizing	1:08	16	10	60	5.5	Anti-back Staining Agent	2 g/l
							Amylase Enzyme	2 g/l
	Rinse	1:08	16	3	RT			
2	Biopolish Enzyme (Cellulase)	1:08	16	3	45 (maintain pH 4.5)		Citric Acid	As require
							Anti pilling Agent	2% OWG
							Anti back Staining Agent	1 g/l
3	Hot Rinse	1:08	16	5	70		Anti back Staining Agent	2 g/l
	Drain							
Hydro-Extraction and Tumble Dry.								

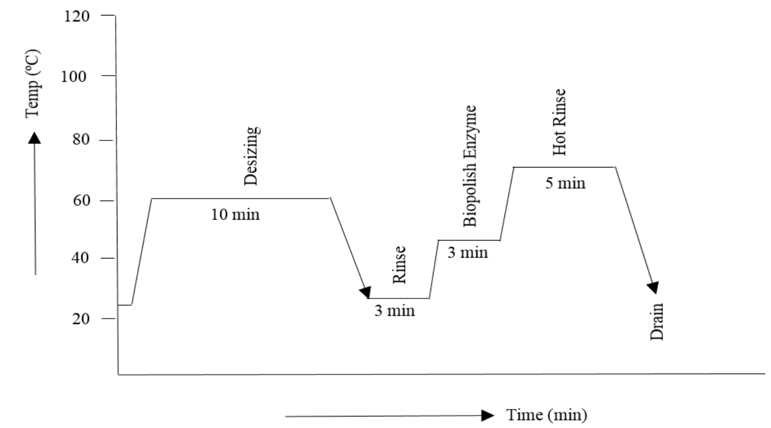

Figure 2: Process curve of Bio-polish enzyme washing

Table 4: Bio-magic washing recipe

Sl	Process Name	Liquor Ratio	Water (Liters)	Time (Min)	Temp (˚c)	pH	Chemical Name	Dossage
1	Desizing	1:08	16	10	60	6.0	Anti-back Staining Agent	2 g/l
	Drain							
2	Aqualess Enzyme	x	x	30 (Charcoal Black)	RT		Bio-Magic	2% OWF
				25 (Dark Indigo)				
				20 (Mid Indigo)				
	Hot Rinse	1:08	16	5	70		Anti-back Staining Agent	2 g/l
	Hydro-Extraction and Tumble Dry.							

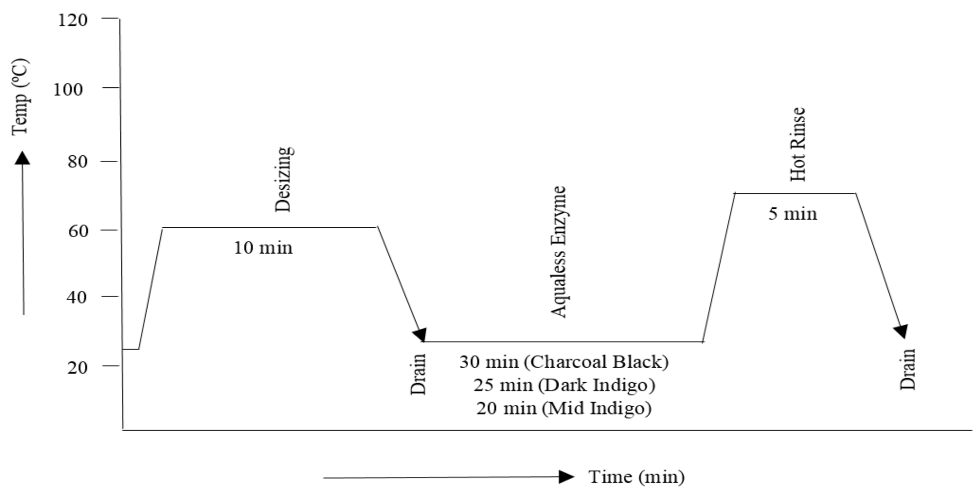

Figure 3: Process curve of Bio-magic enzyme washing.

Figure 4: F1 fabric sample shade after bio-polish and bio-magic wash

Figure 5: F2 fabric sample shade after bio-polish and bio-magic wash.

Figure 6: F3 fabric sample shade after bio-polish and bio-magic wash

Characterization

Fabric Weight

ASTM D3776 Option C test standard was used to determine the measurement of fabric mass per unit area (traditionally referred to as "fabric weight"). Then Option C (small swatch of fabric) was applied. A conditioned specimen was prepared having an area of at least 130 cm^2 (20 in^2). GSM cutter machine was used to cut the fabric specimen for the test. The fabric weight was measured and calculated for GSM value.

Tear Strength

ASTM D1424 standard have been used for tearing strength of fabrics. The testing machine uses a falling pendulum to tear a fabric specimen. It measures the amount of energy required to perform the tearing operation by measuring the peak follow-through angle of the pendulum after the tearing action. The lower the follow-through angle the more energy has been transferred into tearing the specimen. The machine is setup to Jeans after test provide this tearing energy information in grams-force. Our sample size was 100x75 mm. Test apparatus was JAMES HEAL Tear Tester (Model: 1555ELMATEAR), UK.

Tensile Strength

ASTM D5034 standard was used to test the breaking strength and elongation of the fabrics. The ASTM D5034 test method specifies a procedure to determine the maximum force and the elongation at maximum force of textile fabrics using a grab method. Two sets of specimens are prepared, one in the warp (machine) direction and one in the filling (cross) direction. The sample size was 150x100 mm. Test apparatus was JAMES HEAL Universal strength (Model: 1410TITAN-5), UK.

Colorfastness to Crocking

AATCC 8 standard was used to determine colorfastness to crocking. A colored test specimen was rubbed with white crock test cloth under controlled conditions. Color transferred to the white test cloth was assessed by a comparison with the Gray Scale for staining (AATCC Evaluation Procedure 2) or the Chromatic Transference Scale (AATCC Evaluation Procedure 8) and grade was assigned. The sample size was 130x50mm. Test apparatus was JAMES HEAL Crockmaster (Model: 680MD), UK.

Stretch and Recovery

ASTM D3107 standard was used to determine of the amount of fabric stretch, fabric growth, and fabric recovery of fabrics. Size of specimen was 22" bench mark 10". Test apparatus was JAMES HEAL Stretch & Growth (Model: FLEXIFRAME), UK.

Dimensional Stability to Washing (After 3 H/L)

AATCC 135 was used for determination of dimensional changes of fabrics. This test standard was selected because it resembles home laundering process. The specimens are conditioned at a temperature of 21 ± 1 °C (70 ± 2 °F) and 65 ± 2% relative humidity for at least 4 hours prior to testing which is considered the standard atmosphere. Size of Specimen was Specimen Size 610x610mm, Bench mark 460x460mm. Test apparatus was Whirlpool Washing Machine (Model: 3LWTW4825FWO), USA.

Skewness

To determine change in skewness AATCC 179 standard was used. The specimens are conditioned at standard atmosphere. Size of Specimen was 380x380mm, Bench mark 250x250mm. Test apparatus was Whirlpool Washing Machine (Model: LWTW4825FWO), USA.

Color assessment

ASTM D1729-16 was used to specify the visual assessment of the color differences of denim samples that are diffusely illuminated. Size of specimen was 380x380mm. Test apparatus was Light Box, Series: Light Box 600mm (Model: S- Advanced), Germany.

Results and Discussion

Table 5: Characterization of different types of denim fabrics

Fabric Sample		F1		F2		F3	
Description		Bio-magic	Bio-polish	Bio-magic	Bio-polish	Bio-magic	Bio-polish
Fabric Weight	gm/m²	307.8	315.7	359.4	362.2	391.8	395.4
Tear Strength	Warp	11.3	14.4	15.3	16.6	17.2	19.4
	Weft	7.2	8.6	10	11.3	12.6	13.2
Tensile Strength	Warp	170.1	193.5	187.4	203.2	197.5	210.1
	Weft	67.7	78	77.6	85.5	112.4	120.4
Stretch & Recovery	Fabric Stretch 10 Sec After Tension (%)	11.5	13.7	14.2	14.5	15.8	16.3
	Fabric Recovery After 30 Min By Extension (%)	69.3	71.2	72.2	73.8	80.6	82.0
Colorfastness to Crocking	Dry	4.5	4	4	3.5	4	3.5
	Wet	3	2.5	2	2	2.5	2
Dimensional Stability% To Washing (After 3 H/L)	Warp (%)	-1.5	-2.0	-1.0	-1.2	-1.2	-1.5
	Weft (%)	-0.8	-0.7	-1.7	-2.0	-2.5	-2.7
Skewness	(%)	1.8	1.5	1.2	1.0	1.0	0.5

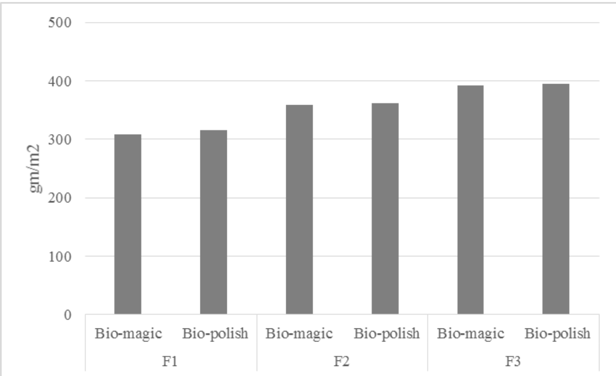

Figure 7: Effect of bio-magic and bio-polish wash on mass per unit area.

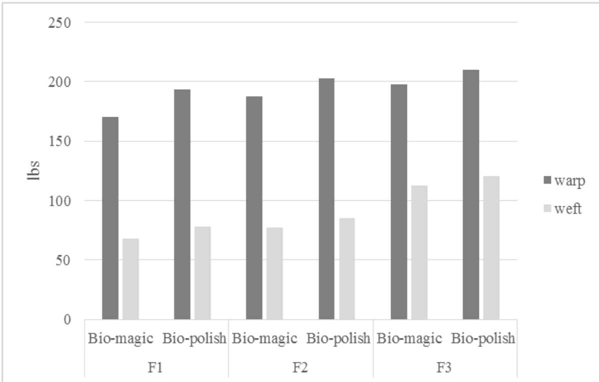

Figure 9: Effect of bio-magic and bio-polish wash on tensile strength.

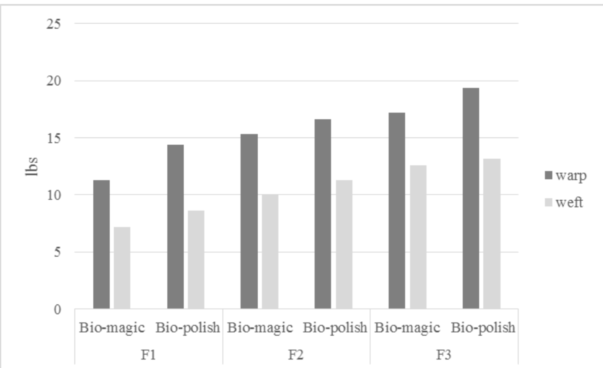

Figure 8: Effect of bio-magic and bio-polish wash on tear strength

Figures 7, 8, 9 illustrate the comparative effects of bio-magic and bio-polish wash treatments on mass per unit area, tear & tensile strength among F1, F2 and F3 respectively. It has been noticed that all fabrics (F1, F2 and F3) exhibit comparatively more weight loss & high tear & tensile strength fall after aqualess Bio-magic treatment. This is because the simultaneous enzyme & mechanical action happens within the machine during aqualess Bio-magic treatment. That's why it shows such results. Also, we noticed that the less GSM fabric the more the weight loss will be (F1). So pre-testing is highly recommended to avoid such issues.

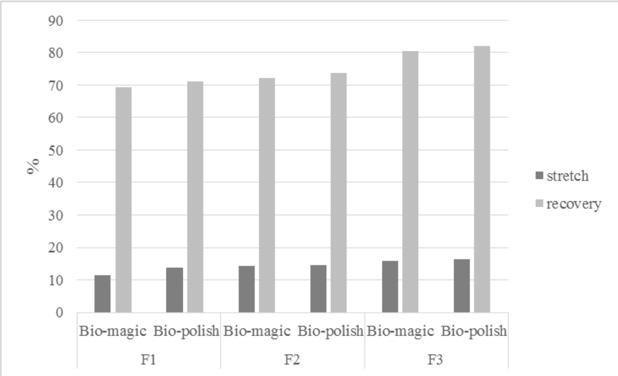

Figure 10: Effect of bio-magic and bio-polish wash on stretch & recovery.

Figures 10 represents the comparative Stretch & recovery effects among F1, F2 and F3 respectively. After bio-magic and bio-polish wash treatments it was found that F1 fabric gets less extension & F3 fabric shows more extension within a constant loads & time (4lbs, 10s). Moreover, F1 exhibits relatively less recovery after 30 min than F1 & F2 fabrics. Here, experimental studies found that the more the fabric GSM the more the fabric stretch & recovery. Furthermore, both wash shows better stretch & recovery performance but bio-polishing treated fabric's stretch & recovery becomes slightly more that appear for more time enzyme treatments which simultaneously degrade the surface color & hydrolysis the cellulose structure resulting makes the fabrics more flexible that facilitates more stretch & recovery of fabric.

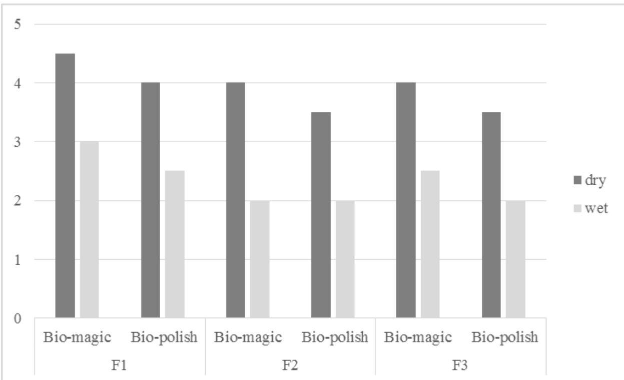

Figure 11: Effect of bio-magic and bio-polish wash on colorfastness to crocking.

Figures 11 illustrate the comparative effects of bio-magic and bio-polish wash on colorfastness to crocking among F1, F2 and F3 respectively. It has been noticed that all fabrics (F1, F2 and F3) exhibit comparatively better crocking fastness after Bio-magic wash rather than Bio-polish treatment. In Bio-polish treatment only enzyme action responsible for color degradation whereas both enzyme & mechanical action happens during aqualess Bio-magic treatment that allows faster & more color bleeding from fabric that's why it shows comparatively much better crocking fastness.

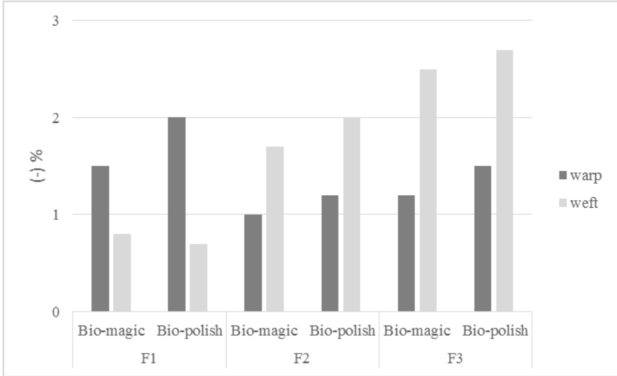

Figure 12: Effect of bio-magic and bio-polish wash on dimensional stability% to washing (after 3 H/L).

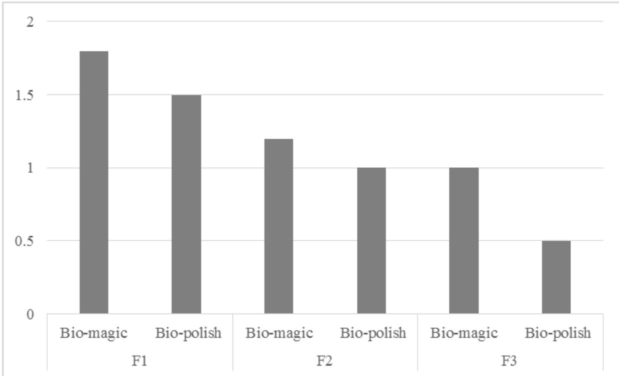

Figure 13: Effect of bio-magic and bio-polish wash on skewness.

Figures 12, 13 illustrate the comparative effects of bio-magic and bio-polish wash on dimensional stability% to washing (after 3 H/L) and skewness between F1, F2 and F3 respectively. We observed that dimensional stability & Skewness to washing is better for all fabrics (F1, F2 and F3) in bio-magic wash due to less time treatments rather than bio-polish washing.

We also confirm the similar shade of F1, F2 and F3 sample after bio-polish and bio-magic wash by color assessment cabinet box D65 and TL-84.

Conclusion

In this research work, we attempted to mitigate the great extent of water in denim industry by developing wash recipe bio-polish: *Trichoderma* based enzyme and bio-magic: *Humicola* based enzyme that applied to wash various qualities & shades denim fabrics. After washing treatments, compared the physical and mechanical performance of both techniques and promote better feasibility of future globe. We measured weight loss, tear strength, tensile strength, crocking, stretch and recovery of fabrics and found that due to the simultaneous enzyme activity and random mechanical activity between machine inner surface and fabric during aqualess bio-magic treatment allowing faster and more color bleeding from fabric and hence a comparatively much superior crocking fastness, but a slight extent weight loss, tear and tensile strength declined compared to bio-polish. Apart from, observed the dimensional stability & Skewness of treated sample, is better for all fabrics (F1, F2 and F3) in bio-magic wash due to less time treatments rather than bio-polish washing that facilitate in making perfect shape & fitted garments. Furthermore, noticed the bio-polish and bio-magic treated different fabrics required shades almost same and no changes of any complain of customer.

Since fresh water has highly scarcity, no chances to waste water consciously. Now, it's prime time to optimum utilization of our natural water resources for better world. In conclusion, we suggest to bio-magic wash techniques to keep down the water consumption large scale in industrial wet processing areas.

Conflict of Interest

The authors have declared no conflict of interest.

Compliance with Ethics Requirements

This article does not contain any studies with human or animal subjects performed by any of the authors.

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References

[1] S. K. Jain and V. P. Singh, "Water crisis," *Journal of Comparative Social Welfare,* vol. 26, no. 2-3, pp. 215-237, 2010/06/01 2010, doi: 10.1080/17486831003687618.

[2] I. Shiklomanov, "Assessment of Water Resources and Water Availability in the World. United Nations Report for the Comprehensive Assessment of the Freshwater Resources of the World," ed: Data archive, CD-ROM from the State Hydrologic Institute of St. Petersburg …, 1998.

[3] W. W. A. Programme, *Water for People, Water for Life: The United Nations World Water Development Report: Executive Summary*. Unesco Pub., 2003.

[4] U. Nations, "Water for people, water for live: The United Nations World Development Report," ed: UNESCO Publishing/Berghahan Books, 2003.

[5] M. Finger, J. Allouche, G. Bannock, R. Baxter, E. J. E. Davis, and Urbanization, "WHO and UNICEF (2000), Global Water Supply and Sanitation Assessment 2000 Report, World Health Organization, UNICEF, Geneva. In the South, populations estimated to be lacking access to improved water supplies and sanitation facilities are: Africa 38 per cent (water) and 40 per cent (sanitation), Asia 19 per cent (water) and 52 per cent (sanitation), and Latin America and the Caribbean 15 per cent (water) and 22 per cent (sanitation)," vol. 11, no. 1, pp. 117-131.

[6] V. J. J. o. e. m. Gupta, "Application of low-cost adsorbents for dye removal–a review," vol. 90, no. 8, pp. 2313-2342, 2009.

[7] B. Hameed, A. Ahmad, and N. J. C. E. J. Aziz, "Isotherms, kinetics and thermodynamics of acid dye adsorption on activated palm ash," vol. 133, no. 1-3, pp. 195-203, 2007.

[8] H. J. W. Ali, Air, and S. Pollution, "Biodegradation of synthetic dyes—a review," vol. 213, no. 1, pp. 251-273, 2010.

[9] A. K. R. J. A. M. Choudhury and T. f. Environmental, "Eco-friendly dyes and dyeing," vol. 2, pp. 145-76, 2018.

[10] T. Gulzar, T. Farooq, S. Kiran, I. Ahmad, and A. Hameed, "Green chemistry in the wet processing of textiles," in *The impact and prospects of green chemistry for textile technology*: Elsevier, 2019, pp. 1-20.

[11] B. R. Babu, A. Parande, S. Raghu, and T. P. J. T. Kumar, "Textile technology," vol. 11, pp. 110-122, 1995.

[12] T. Gulzar, T. Farooq, S. Kiran, I. Ahmad, and A. Hameed, "1 - Green chemistry in the wet processing of textiles," in *The Impact and Prospects of Green Chemistry for Textile Technology*, I. Shahid ul and B. S. Butola Eds.: Woodhead Publishing, 2019, pp. 1-20.

[13] P. C. Vandevivere, R. Bianchi, W. J. J. o. C. T. Verstraete, E. Biotechnology: International Research in Process, and C. Technology, "Treatment and reuse of wastewater from the textile wet-processing industry: Review of emerging technologies," vol. 72, no. 4, pp. 289-302, 1998.

[14] P. Senthil Kumar and E. Gunasundari, "Sustainable wet processing—an alternative source for detoxifying supply chain in textiles," in *Detox Fashion*: Springer, 2018, pp. 37-60.

[15] S. Saxena, A. Raja, and A. Arputharaj, "Challenges in sustainable wet processing of textiles," in *Textiles and clothing sustainability*: Springer, 2017, pp. 43-79.

[16] V. Panwar, J. N. Sheikh, and T. Dutta, "Sustainable Denim Bleaching by a Novel Thermostable Bacterial Laccase," *Applied Biochemistry and Biotechnology,* vol. 192, no. 4, pp. 1238-1254, 2020/12/01 2020, doi: 10.1007/s12010-020-03390-y.

[17] T. M. Hsu *et al.*, "Employing a biochemical protecting group for a sustainable indigo dyeing strategy," *Nature Chemical Biology,* vol. 14, no. 3, pp. 256-261, 2018/03/01 2018, doi: 10.1038/nchembio.2552.

[18] F. Ş. Fidan, E. K. Aydoğan, and N. Uzal, "Multi-dimensional Sustainability Evaluation of Indigo Rope Dyeing with a life cycle approach and hesitant fuzzy analytic hierarchy process," *Journal of Cleaner Production,* vol. 309, p. 127454, 2021/08/01/ 2021, doi: https://doi.org/10.1016/j.jclepro.2021.127454.

[19] V. Buscio, M. Crespi, and C. Gutiérrez-Bouzán, "Sustainable dyeing of denim using indigo dye recovered with polyvinylidene difluoride ultrafiltration membranes," *Journal of Cleaner Production,* vol. 91, pp. 201-207, 2015/03/15/ 2015, doi: https://doi.org/10.1016/j.jclepro.2014.12.016.

[20] X. Li, K. Wang, M. Wang, W. Zhang, J. Yao, and S. Komarneni, "Sustainable electrochemical dyeing of indigo with Fe(II)-based complexes," *Journal of Cleaner Production,* vol. 276, p. 123251, 2020/12/10/ 2020, doi: https://doi.org/10.1016/j.jclepro.2020.123251.

[21] V. J. T. W. Zaffalon, "Climate change, carbon mitigation and textiles," vol. 160, pp. 34-35, 2010.

[22] S. Judd, *The MBR book: principles and applications of membrane bioreactors for water and wastewater treatment*. Elsevier, 2010.