Avrupa Bilim ve Teknoloji Dergisi
Özel Sayı 32, S. 1203-1206, Aralık 2021

Araştırma Makalesi

www.ejosat.com ISSN:2148-2683

European Journal of Science and Technology
Special Issue 32, pp. 1203-1206, December 2021

Research Article

Effects of Anhydrous Enzymes Usage in Denim Washing on Fabric Tear Strength

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(International Conference on Design, Research and Development (RDCONF) 2021 – 15-18 December 2021)

(**DOI:** 10.31590/ejosat.1055060)

ATIF/REFERENCE: Açıkgöz-Tufan, H., Emekdar, E., Şahin, U.K., Şensoy, M., Tunalı, Y. & Güngör, H. (2021). Effects of Anhydrous Enzymes Usage in Denim Washing on Fabric Tear Strength. *European Journal of Science and Technology*, (32), 1203-1206.

Abstract

In this study, an anhydrous enzyme washing process was produced as an alternative for stone washing which is one of the major steps of denim production. For this concept, 3 different fabric contents and 4 different anhydrous washing enzymes were used, the visual appearance as well as the strength of the products that was obtained after washing were compared with the products that was made with conventional stone washing. The results of the physical performance and visual tests showed that the developed anhydrous enzyme washing process can replace the stone washing process. In addition, up to 12 liters of water was saved on a product basis and the use of pumice stone was completely eliminated. Therefore, product costs were also reduced while natural resource consumption was reduced.

Keywords: Anhydrous Enzyme, Denim Washing, Tear Strength.

Denim Yıkamada Susuz Enzim Kullanımının Kumaş Yırtılma Mukavemetine Etkileri

Öz

Bu çalışmada denim sektörünün en önemli adımlarından biri olan taş yıkama prosesine alternatif olabilecek bir susuz enzim yıkama prosesi geliştirilmiştir. Bu kapsamda 3 farklı kumaş içeriği ve 4 farklı susuz yıkama enzimi kullanılmış olup yıkama sonrası elde edilen ürünler görsellik ve mukavemet açısından konvansiyonel taş yıkama yapılmış ürünlerle karşılaştırılmıştır. Yapılan fiziksel performans ve görsel testlerin sonuçları geliştirilen susuz enzim yıkama işleminin taş yıkama prosesinin yerini alabileceğini göstermiştir. Bunun yanı sıra ürün bazında 12 litreye kadar su tasarrufu sağlanmış ve ponza taşının kullanımı tamamen ortadan kaldırılmıştır. Böylece doğal kaynak tüketimi azaltılırken ürün maliyetlerinin de düşmesi sağlanmıştır.

Anahtar Kelimeler: Susuz Enzim, Denim Yıkama, Yırtılma Mukavemeti.

1. Introduction

The washing process in the denim sector is an industry branch which consumes a lot of water, differ the processes according to the method and technologies, and vary the auxiliary chemicals and dyestuffs used according to the process and the product (Babalık, 2012). In the denim garment production chain, one of the processes with significant input costs and environmental impacts is the washing process. In addition to physical operations, wet chemical processes also vary in washing processes. This diversity brings more water consumption with it and it is affected significantly in terms of the environment due to the waste water generated (Ben Hmida & Ladhari, 2016).

The stone washing process, which plays a key role in the denim sector and causes significant input costs in the 'washing' process, is a process applied to give an aged appearance to the denim products in order to meet the customer expectations and needs. While 12 liters of water, 17 g of stone enzyme and 2 kg of pumice stone are needed per product to achieve this image on denim; the processing time varies between 10 and 100 minutes depending on the degree of effect that we want to achieve on denim. Also, manpower is needed to clean the pumice stone which remains in the machine at the end of the process this brings potential harm to worker (Riddselius & Maher, 2010; Associates., 2018; Khan & Jintun, 2021).

Undesirable deformations occur depending on the time that is spent by the denim product in the machine during stone washing. These deformations cause a decrease in fabric strength, wear on the belt, breakage in the belt and leg chain stitches, fraying in the corners of the back pockets, and tears in the pocket bags. These deformations are damages that are not approved by the customer and will not satisfy the customer.

While the pumice stone used in the stone washing process is 1,200 tons per year, its annual cost is 650,000-750,000 TL depending on the price change. In addition to this covered cost, such a project was needed to reduce the excess refinment costs and chemical costs caused by the stone, and most importantly, the water costs (Fiber2Fashion, 2006).

It was needed to reduce the labor force used because the pumice stones must be filled and discharged into the machine for grinding stage in the washing process and the stone must be removed from the product. For approximately 120 products, the stone washing process takes 10 minutes for filling, 15 minutes for unloading, and 15 minutes for stone cleaning. Thanks to the newly developed anhydrous enzyme, the invisible cost that is added to the product will be eliminated since no stone will be used. In addition, stone filling and unloading processes, which require physical strength, will also be positively affected in terms of worker health.

When the pumice stone used is mixed with the process water, it creates a serious workload for the refinment process. In addition to the physical waste stone removal from the process water that is sent to the treatment, the smaller stone particles that cannot be removed are mixed with the refinment sludge in excessive amounts.

At this point, it was decided to develop an anhydrous enzyme project to eliminate all these needs. In normal conventional washings, water, pumice stone, cellulosic enzymes and chemicals that prevent back dyeing are used together with the product. In this anhydrous enzyme process water, stone and chemicals that prevent back dyeing were removed and anhydrous enzyme was applied on the moistened products by scattering method. Since the absence of water in the environment prevents back dyeing and it is used instead of stone in anhydrous enzyme, only anhydrous enzyme was used.

The products that are put into the machine are moistened with a water draining method and a light squeezing process is performed according to the desired effect on the product. Then, enzyme selection is made according to fabric type and product dry weight. Since the enzyme selection will differ according to the specified criteria, the correct enzyme selection is very important in terms of application efficiency. The enzyme sprinkled on the product is anhydrous and the products are rotated on both sides in the machine until the required effect is achieved.

After the anhydrous enzyme process is completed, washing with soda (sodium bicarbonate) is carried out to terminate the enzyme activity. Tearing strength was measured in order to understand the effect of anhydrous enzyme process on the products. With the R&D activities that are carried out, the widespread use of the enzyme processing method in anhydrous environment, which can be applied in all product groups, will allow significant water savings

2. Material and Method

In the study, the most preferred fabric blends for denim trousers were used and their detailed contents are shown in Table 1. In addition, 4 different types of anhydrous enzyme chemicals developed with different chemical manufacturers were used. While developing anhydrous enzyme chemicals, materials that do not harm the strength of the product and are compatible with the view that is obtained as a result of the existing stone process were preferred. The most important features expected from anhydrous enzyme are; not harming the product, not having a negative effect on its weight, and having a formula that will not cause irreversible damage to the product such as color.

Table 1. Variables of the study

Variables	***Levels***
Fabric composition	a) 99% cotton - 1% elastane b) 96% cotton - 3% polyester - 1% elastane c) 50% organic cotton - 45% cotton - 3% T400 - 2% elastane
Enzyme	A, B, C, D

The obtained anhydrous enzyme was tested on different fabric types and the results were checked with both visual and test methods. After the tests, enzyme optimization was carried out according to the fabric type, and the differences caused by the product structure and color differences in the process were tried to be caught.

The steps and durations applied in washing comparisons are shown in the Table 2. In both processes, pre-washing, hot rinsing washing, main washing, rinsing, spinning and drying processes were applied at the same time. In the stone washing step, 30 liters of water, 10 kg of stone, 30 g of stone enzyme and 15 g of dispersant were added to the machine for 4.1 kg of denim fabric, while in the enzyme washing step, the required amount of enzyme was sprinkled on the fabrics.

Table 2. Steps and durations of stone and enzyme washing processes

Stone Washing	***Enzyme Washing***
Pre-washing (10 min)	*Pre-washing (10 min)*
Hot rinsing washing (2 min)	*Hot rinsing washing (2 min)*
Stone washing (40 min)	*Enzyme washing (40 min)*
Rinsing (2 min)	*Rinsing (2 min)*
Spinning	*Spinning*
Drying	*Drying*

Tear strength (ASTM D-1424) and pH (ISO 3071) tests were applied to the fabrics obtained as a result of washing processes. While examining the physical effects of the applied processes on the product via performing tear strength, it was examined whether the enzyme treatment performed at certain pH ranges had an effect on the fabric with the pH test.

Figure 1. Addition of anhydrous enzyme to wet samples (left), adding pumice stones to the pre-stonewashing process (right)

In the obtained results, the surface effects and color harmony are visually compared with the products that were made with normal conventional washings. In addition, the tear test is performed with the manual control method on the determined effect sample and the degree of tearing is also examined here.

The main goal on the compared samples is to achieve the same surface effect, which is obtained with pumice stone, with anhydrous enzyme. The results were evaluated according to whether they had less or more effects, and it was aimed to catch the right sample color by changing the necessary duration arrangements or by changing the amount of the anhydrous enzyme.

3. Results and Discussion

The tear strength results obtained as a result of the study are shown in Table 3.

Data of Table 3 are used to produce individual main effect plots for tear strength values in warp and weft directions.

Table 3. Tear strength values of fabrics obtained as a result of 4 different anhydrous enzyme treatments used on 3 different fabric content

Fabric Content		Before Washing		After Washing	
		Weft (gf)	Warp	Weft	Warp
a)99% cotton 1% elastane	A	4896	6272	2688	4128
	B	6336	6400	5504	5280
	C	6336	6400	5728	5664
	D	6304	6400	5652	5312
b)96% cotton 3% polyester 1% elastane	A	6368	6400	5060	5280
	B	6304	6400	6208	5312
	C	6400	6400	6400	6272
	D	6400	6400	5920	5536
c)50% organic cotton 45% cotton 3% T400 2% elastane	A	4160	6208	3776	5888
	B	4480	6080	4384	6048
	C	4672	6208	4544	6400
	D	4544	6080	4448	5952

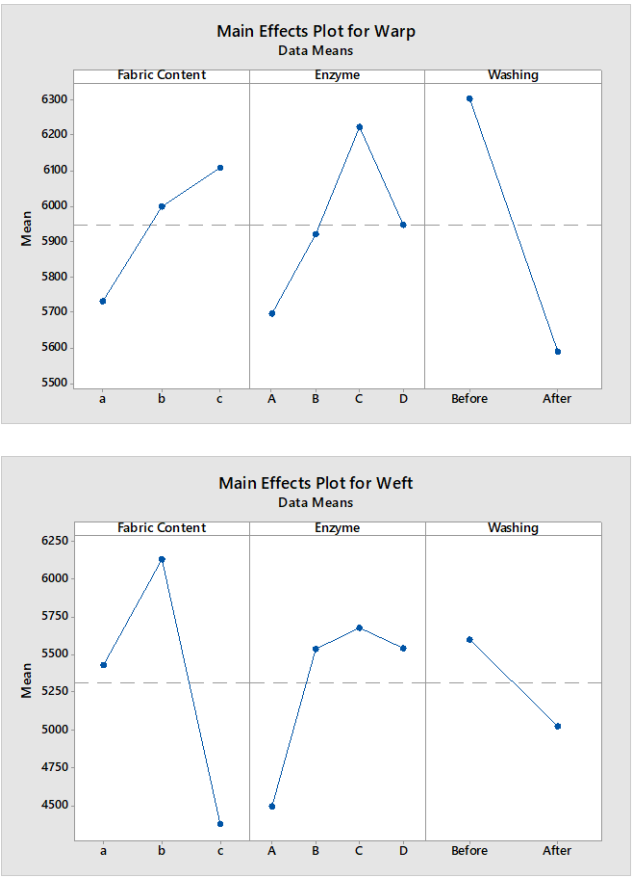

Figure 2. Main effects plot of the study for fabric content, enzyme and washing on warp(up) and weft(down)

It is apparent from Figure 2, that washing with detergent cause approximately 11% decrease in tear strength regardless of direction of the test. Moreover, the effect of enzyme used were parallel in both directions showing highest strength loss when enzyme A is used and only limited loss with enzyme C. However, the variation in fabric content affected final tear strength values differently in warp and weft directions. Increasing polyester percentage in fabric fiber content causes tearing strength to increase as expected.

As a result of the pH tests performed on the samples, pH values in the range of 6.84 -7.01 were observed. In Figure 2, there are photographs of the experiments made with four different anhydrous enzymes, all enzyme types that are used gave similar results in terms of appearance in the final product.

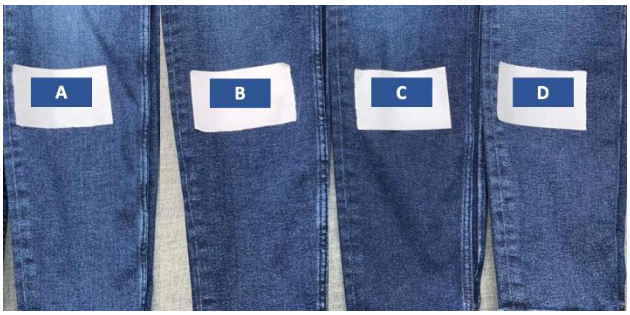

Figure 3. After washing images of the samples obtained as a result of the experiments with A, B, C and D enzymes

As it can be seen from the samples that are obtained as a result of stone washing and anhydrous enzyme washing shown in Figure 3, the desired stone washing effects could also be obtained with the anhydrous enzyme washing process. Different results have been obtained for different fabric mixtures, and suitable anhydrous enzyme types or combinations can be preferred to achieve the desired effect.

Figure 4. Samples obtained as a result of stone washing (left) and anhydrous enzyme washing (right)

In addition to these, reduction of natural resource consumption and cost reduction have also been achieved. In the study, 12 liters of water was saved for one denim trousers, while 17 g of stone enzyme and 2 kg of pumice stone were completely eliminated and the cost of the product decreased by 13%.

4. Conclusion

In this study, an anhydrous enzyme washing process, which will be an alternative to the conventional stone washing method that has been used for years, has been developed. In this direction, experiments were carried out with 3 different fabric mixtures and 4 different anhydrous enzymes and results were compared with the conventional method in terms of product performance and resource consumption. The highest strength loss was seen after treatment with enzyme A while the best strength results were achived with enzyme C. Strength increase was observed when polyester was added to fiber blend. Moreover, solid wastes that are caused by heavy stone usage and cleaning with excess water in conventional washings for purifying the stone dust on the product have been eliminated and 25.6% water savings have been achieved.

5. Acknowledge

The authors would like to thank R&D Center of Su Global for their support throughout the study. Results presented here are part of preliminary studies as part of the project entitled “Application of Stone Washing Process via Novel Anhydrous Enzyme Method and Conducting Trials on Present Products (Taşlama Prosesinin Yenilikçi Susuz Enzim Yöntemi ile Uygulanması ve Mevcut Ürünler Üzerinde Denenmesi)” (Project ID: RD-002) conducted under R&D Center of Su Global.

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