

Research Article

Improvement of Hand Feeling Properties of Fabrics Containing Recycled Fibers by Enzymatic Treatments

Süleyman Şamil Çelebi^{1*}, Burcu Yılmaz^{2*}

¹TYH Textile Research and Development Center, Istanbul, Türkiye
(ORCID: 0009-0006-0770-3616) samilcelebi@tyh.com.tr

²Marmara University, Textile Engineering Department, Istanbul, Türkiye
(ORCID: 0000-0003-0885-8151) burcuyilmaz@marmara.edu.tr

* Süleyman Şamil Çelebi: samilcelebi@tyh.com.tr (+90 506 173 33 93)

(First received September 17, 2023 and in final form December 26, 2023)

Reference: Çelebi S., Ş., Yılmaz, B. Improvement of Hand Feeling Properties of Fabrics Containing Recycled Fibers by Enzymatic Treatments. The European Journal of Research and Development, 3(4), 321-332.

Abstract

Clothing is one of the most basic needs for human survival. For this reason, the textile sector is one of the sectors with the highest consumption. However, the use of chemicals, water and natural resources in this large sector has increased to unbelievable levels. Today, there is a need for studies under the name of sustainability due to increasing population and decreasing natural resources. The most basic element in the studies is observed as recycling. However, it is observed that the hand feeling properties of fabrics containing recycled fibers are not meet with market needs. In this study, different enzyme combinations were applied to undyed fabrics by conventional methods in order to improve the hand feeling of fabrics containing recycled fibers. The subjective hand feeling evaluations, whiteness-yellowness values and hydrophilicity values of the obtained fabrics were compared. As a result of the tests, positive or negative changes were observed in the fabric behavior and these changes were evaluated as a result of the application of different enzyme combinations with different methods. Enzyme applications positively affected the hydrophilicity of the fabric. Positive and negative results of different enzyme applications were observed in the whiteness-yellowness values of the fabric.

Keywords: Sustainability, recycling, enzyme, hand feeling

1. Introduction

Life consists of three basic needs including nutrition, shelter and clothing. Clothing, which is among the most important needs of life, is one of the biggest areas that individuals need for their lives. People are constantly spending on clothing to keep up with competitive trends in fashion. In Europe, statistics show a 40% increase in clothing expenditure and a growing momentum as fashion dynamics change (Hole & Hole, 2020).

Textile sector is one of the sectors with high environmental impact. For this reason, it is mandatory for the sector to act sensitively in terms of reuse in production processes and consideration of recycling afterwards (Doba et al., 2022). In addition to the environmental problems caused by textile waste generation, the textile industry from fiber to garment production is one of the most polluting and waste producing sectors in the world. According to the research conducted by MADE-BY (2013) on the comparison of various fibers in terms of sustainability, it has been observed that both natural and synthetic fibers obtained by conventional production methods are far behind in sustainability ranking (Utebay et al., 2019).

Enzymatic processes have gained popularity in the textile industry due to environmentally friendly and energy-saving alternatives (Kabir & Koh, 2021). Enzyme-based biotechnology promises a bright future for its application in the textile industry and its contribution to textile sustainability (Shen & Smith, 2015).

The raw material of a fabric has a significant influence on its functional properties. However, fabrics used in apparel manufacturing must offer comfort, protection, ease of maintenance, durability and aesthetics (Sanches et al., 2015).

Textile recycling has become essential for today's textile industry. However, it has been observed that there is a deterioration in the hand feeling properties during the recycling stage. The aim of this study is to improve the hand feeling properties of fabrics containing recycled fibers without harming the nature by using natural substances and to contribute to the literature on this subject by encouraging recycling. In this context, firstly, different enzymes (pectinase, cellulase, laccase) were applied in different combinations on recycled fabrics by conventional methods. Then, subjective hand feeling measurement, whiteness-yellowness measurement and hydrophilicity measurements were carried out.

2. Materials and Methods

2.1. Material

In this study, knitted fabric containing 100% recycled fibers were used. The knitting structure of the fabric was single jersey. The fabric blend was 50% recycled cotton from pre-consumer waste and 50% recycled polyester. Enzyme processes were applied to the

recycle fabric as a raw fabric before dyeing processes. The basis weight of was 171 g/m². The fabrics were cut so that the material weight was 5 g for each process. The fabric used in the study was developed and supplied by TYH Textile. In the study, recycled fabrics were treated with different enzymes. The enzymes used in the study are given in table 1.

Table 1: Enzymes used in the study

Type of enzymes	Enzymes Name	Producer
Pectinase	Scourzym L	ALFA KIMYA
Cellulase	Cellusoft Prime37500 L	ALFA KIMYA
Laccase	Laccase Enzym	ATAMAN CHEMICALS

2.2. Methods

Different enzyme combinations were applied to the same fabric, and the effects on the fabric's hand feeling properties were observed. The optimum parameters for each enzyme were determined based on previous studies, and all experiments were conducted at these parameters (Yılmaz, 2010). And all bath ratios were 20:1. Throughout the study, all processes were carried out by conventional methods. An experimental plan was created to observe the results of enzyme combinations. The experimental plan is given in table 2.

Table 2: Experimental plan

Fabric Code	Enzyme	Temperature (°C)	Concentration (g/L)	Time (min)	pH
P	Pectinase	55	10	30	8
C	Cellulase	55	10	30	5
PC1	Pectinase → Cellulase	55	10 → 10	30 → 30	8 → 5
PC2	Pectinase + Cellulase	55	10 + 10	30 + 30	8 + 5
L	Laccase	55	10	40	5
PCL1	Pectinase → Cellulase → Laccase	55	10 → 10 → 10	30 → 30 → 40	8 → 5 → 5
PCL2	Pectinase + Cellulase + Laccase	55	10 + 10 + 10	30 + 30 + 40	8 + 5 + 5
PL1	Pectinase → Laccase	55	10 → 10	30 → 40	8 → 5
PL2	Pectinase + Laccase	55	10 + 10	30 + 40	8 + 5
PLC1	Pectinase → Laccase → Cellulase	55	10 → 10 → 10	30 → 40 → 30	8 → 5 → 5
PLC2	Pectinase + Laccase + Cellulase	55	10 + 10 + 10	30 + 40 + 30	8 + 5 + 5

Fabrics treated with a single enzyme

The P, C and L coded fabrics used in this section. 5 g of fabric was used for each process. All enzymes were treated at the optimum values determined in separate baths for the specified time. After the time, each enzyme was washed at 80°C for 10 minutes. After washing, the fabrics were dried at room temperature.

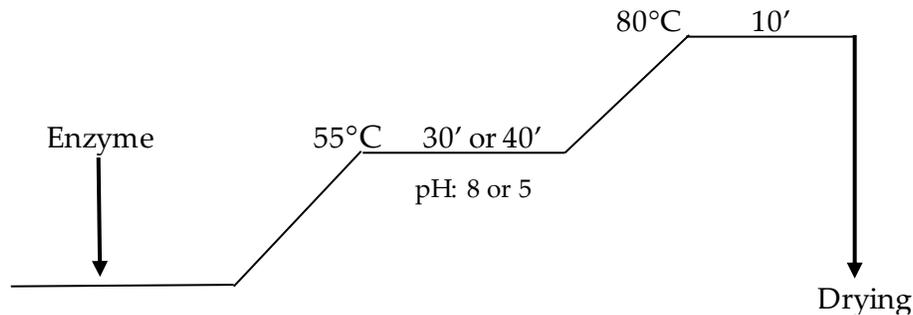


Figure 1: Application process of P, C and L coded fabrics

Fabrics treated with multiple enzymes, with drying after each enzyme treatment

The PC1, PCL1, PL1, and PLC1 coded fabrics used in this section. The fabrics in this section were treated with pectinase enzyme first, followed by a washing process at 80°C for 10 minutes. Then, the fabric was dried at room temperature. After the fabric dried, a second enzyme was applied, and the washing and drying process was carried out again. For PCL1 and PLC1 coded fabrics, a third enzyme was added and the same processes were repeated.

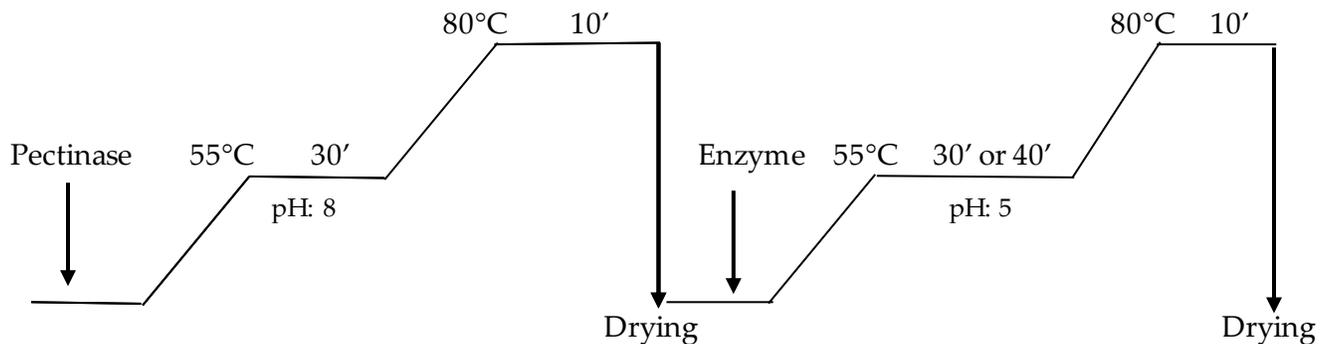


Figure 2: Application process of PC1 and PL1 coded fabrics

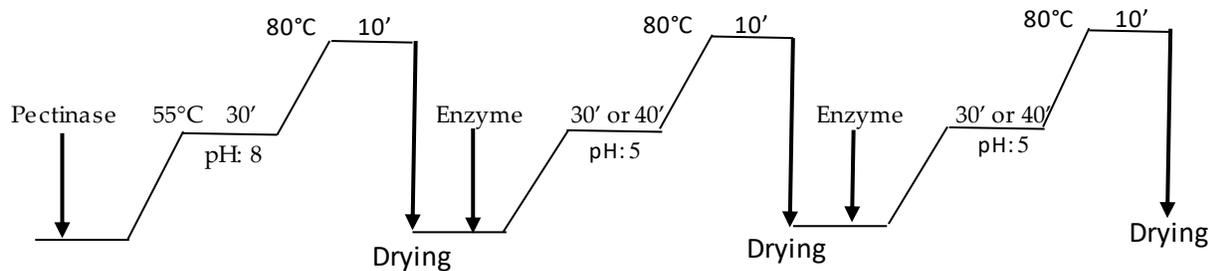


Figure 3: Application process of PCL1 and PLC1 coded fabrics

Fabrics treated with multiple enzymes in the same bath

The PC2, PCL2, PL2, and PLC2 coded fabrics used in this section. The fabrics in this section were treated with pectinase enzyme first, then, the next enzyme was added to the bath without removing the fabric from the bath, and the pH level of the bath was adjusted to 5. For PC2 and PL2 fabrics, washing and drying were performed after this process. For PCL2 and PLC2, the fabric was not removed from the bath, and the third enzyme was added. The fabric continued to be processed in the bath for the duration of the process. The process for these fabrics was completed by performing the washing and drying process.

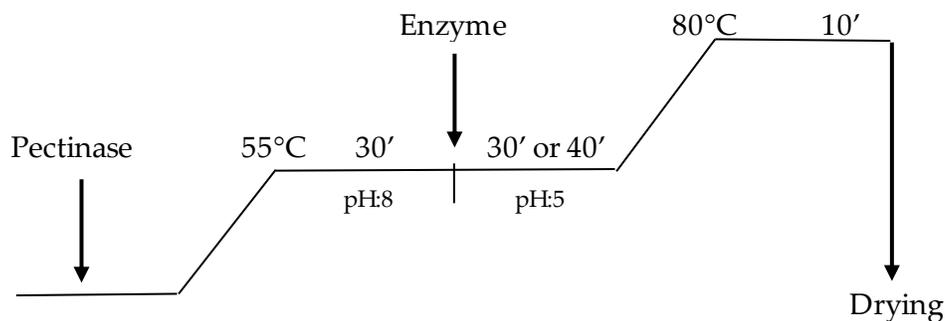


Figure 4: Application process of PC2 and PL2 coded fabrics

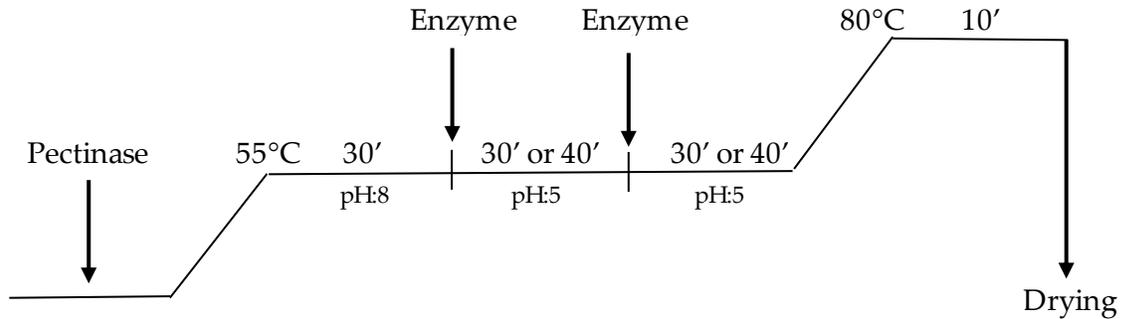


Figure 5: Application process of PCL2 and PLC2 coded fabrics

3. Results

Fabrics have been numbered for all tests, and the numbers are given in table 3.

Table 3: Fabric codes for tests

R	Raw Fabric
P	Pectinase
C	Cellulase
PC1	Pectinase → Cellulase
PC2	Pectinase + Cellulase
L	Laccase
PCL1	Pectinase → Cellulase → Laccase
PCL2	Pectinase + Cellulase + Laccase
PL1	Pectinase → Laccase
PL2	Pectinase + Laccase
PLC1	Pectinase → Laccase → Cellulase
PLC2	Pectinase + Laccase + Cellulase

Subjective Hand Feeling Test Findings

From past to present, studies have been carried out on the subjective evaluation of hand feeling characteristics. On the basis of these studies, a jury is formed and the data from the jury are interpreted within the scope of statistical science (Sülar & Okur, 2012).

In this study, 7 female and 4 male jury members between the ages of 27 and 56 with more than 5 years of experience in the textile sector were selected. These jury members were asked to rank the fabrics from soft to hard. The softest fabric was given the highest evaluation score of "12 points" and the hardest fabric was given the lowest evaluation score of "1 point". So, the jury members scored 12 fabrics between 1 and 12. Then the arithmetic averages of the scores given on fabric basis were taken. The scores for the fabrics in the study are given in table 4.

Table 4: Jury scoring and softness sorting

Fabric Code Jury No	R	P	C	PC1	PC2	L	PCL1	PCL2	PL1	PL2	PLC1	PLC2
1	7	10	4	8	5	6	9	3	11	1	12	2
2	3	11	10	12	8	9	6	5	2	4	7	1
3	6	10	8	11	9	7	3	2	4	5	12	1
4	1	12	7	11	4	6	8	2	5	9	10	3
5	3	7	2	9	12	5	8	10	4	6	11	1
6	5	8	7	9	10	6	3	2	4	11	12	1
7	1	2	5	7	4	6	8	10	9	3	12	11
8	3	12	1	8	4	5	7	2	6	9	11	10
9	2	12	5	3	1	11	9	7	4	6	8	10
10	3	7	12	8	10	11	4	2	5	1	9	6
11	2	9	7	12	6	8	4	3	10	1	11	5
Average Score	3.27	9.09	6.18	8.90	6.63	7.27	6.27	4.36	5.81	5.09	10.45	4.63
Sorting	12	2	7	3	5	4	6	11	8	9	1	10

PLC1>P>PC1>L>PC2>PCL1>C>PL1>PL2>PLC2>PCL2>R

In the study, while evaluating the hand feeling test results, the first six samples were evaluated as fabrics with good hand feeling and the last six samples were evaluated as fabrics with undesirable hand feeling properties.

According to the results obtained, when the enzymes applied alone were evaluated (P, C and L), it was observed that the enzymes that provided good touch were pectinase, laccase and cellulase, respectively. In general, it was observed that the treatment of the fabrics with different enzymes in the same bath without drying process had a negative effect on the fabric hand feeling properties, while the fabric samples with drying process

after each enzyme application improved the hand feeling. When the results of fabrics PLC1, PLC2 and PCL1, PCL2 are examined, this situation is clearly seen. When we look at PC2 and PL2, the touch of the fabric sample was negatively affected when treated with pectinase and laccase enzymes in the same bath without drying. However, the use of pectinase and cellulase enzymes together improved the touch. When the results of PL1 and PL2 were analysed, the application of pectinase and laccase enzymes together in the same bath or with drying process, negatively affected the hand feeling result. Therefore, it is thought that there is an incompatibility between pectinase and laccase enzymes. When the results of fabrics PCL2 and PLC2 were evaluated, it was clearly observed that the hand feeling properties of fabrics containing recycled fibers were adversely affected when subjected to long processes in the same bath.

Whiteness and Yellowness Index Measurement

For the measurement of whiteness and yellowness index, the fabric was folded and placed neatly in the spectrophotometer. Whiteness index was measured according to AATCC 110-2005 standard. The standard for measuring the yellowness index is ASTM D 1925-70. The test results were given in table 5.

Table 5: Whiteness- Yellowness Index

Fabric Code	Whiteness Index	Yellowness Index	Fabric Code	Whiteness Index	Yellowness Index
R	28.25	17.91	PCL1	29.75	16.55
P	25.50	15.12	PCL2	27.00	18.45
C	37.30	14.23	PL1	28.60	17.97
PC1	36.45	14.58	PL2	27.90	18.33
PC2	35.75	15.28	PLC1	30.85	16.61
L	28.60	17.92	PLC2	25.90	19.16

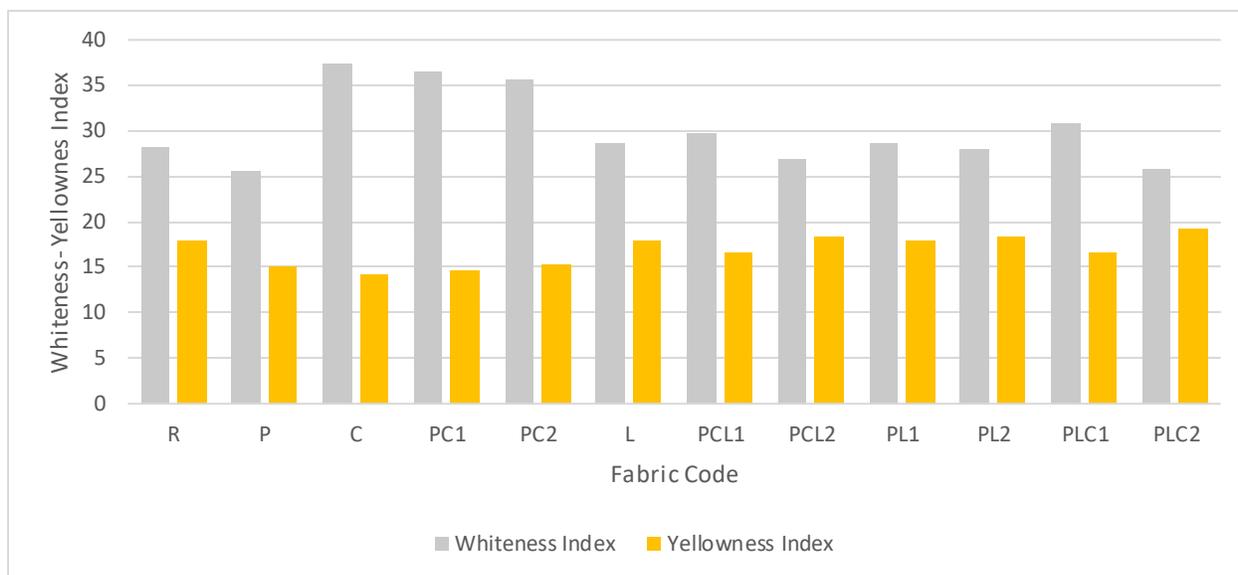


Figure 6: Graph of whiteness-yellowness index

The whiteness index value of the C coded fabric was found to be the best. In this regard, the highest whiteness degree was observed with the application of cellulase enzyme. PC1 and PC2 followed the C coded fabric, which gave the best whiteness. The whiteness index of the P coded fabric was low when pectinase enzyme was used alone. However, the whiteness index of the PC1 and PC2 coded fabrics, which were obtained by adding cellulase enzyme to this fabric. When the test results were analysed, processing fabrics consecutively decreased the whiteness value, but applying drying operations in between processes increased the whiteness degree. And laccase enzyme alone did not have a significant effect on the whiteness index of the fabric. However, when used with other enzymes, laccase enzyme reduced the whiteness degree. In general, the yellowness values were proportional to the whiteness values.

Hydrophilicity Test

Hydrophilicity determination by drop test was carried out in accordance with AATCC 79-2007 test standard.

Table 6: Absorption time

Fabric Code	Absorption Time (sec)	Fabric Code	Absorption Time (sec)
R	60	PCL1	10.30
P	18	PCL2	9.25
C	32	PL1	20.6

PC1	11	PL2	15
PC2	9	PLC1	14.3
L	53	PLC2	5.25

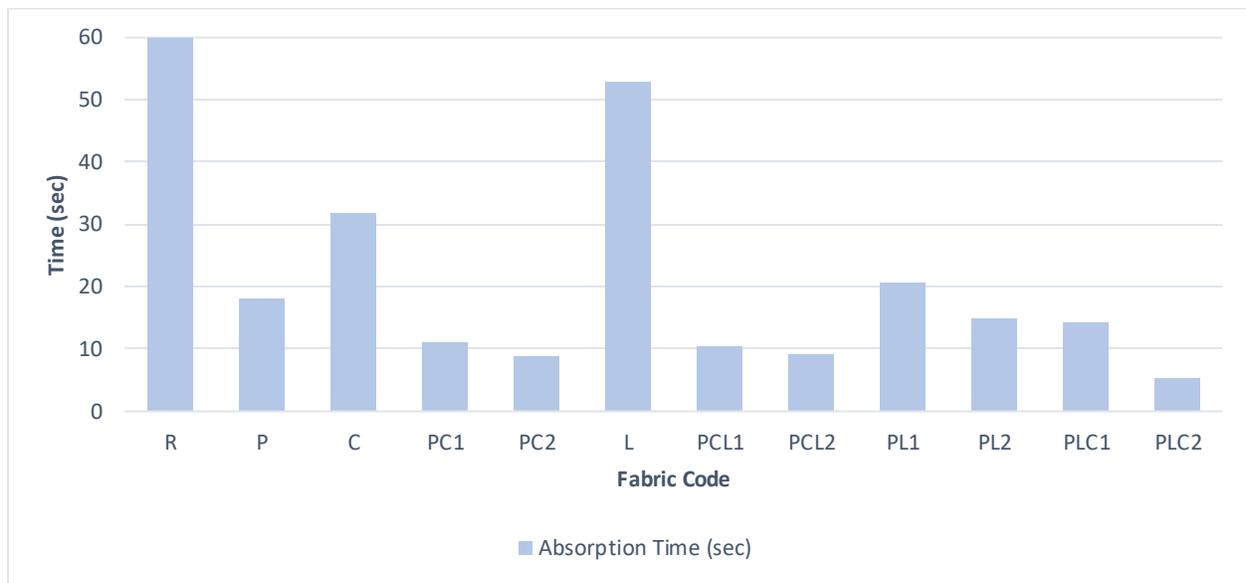


Figure 7: Graph of absorption time

The three different enzymes used had different hydrophilicities, with pectinase enzyme providing the highest hydrophilicity and laccase enzyme providing the lowest hydrophilicity. It was clearly seen that the treatment of fabrics with enzymes has a positive effect on fabric hydrophilicity. In addition, the increase in the amount of enzyme added to the process resulted in an increase in the hydrophilicity value. When analysed as a process, consecutive processes resulted in better hydrophilicity in fabrics than processes with drying steps in between.

4. Discussion and Conclusion

Within the scope of this study, studies have been carried out to improve the hand feeling properties of fabrics containing recycled fibers without harming the nature by using

natural materials. In this context, firstly, different enzymes (pectinase, cellulase, laccase), in different combinations, were applied on recycled fabrics by conventional methods. And examination of the fabric hand feeling, whiteness-yellowness values, and hydrophilicity behavior was conducted.

When the fabric hand feeling properties were analysed, it was found that pectinase, laccase and cellulase enzymes were the enzymes that provided the softest touch, respectively. And the hand feeling properties of fabrics containing recycled fibers were negatively affected by long treatments in the same bath.

The whiteness degree provided by the cellulase enzyme was the highest, while the whiteness degree provided by the pectinase enzyme was the lowest, when the whiteness and yellowness values were analysed. When the test results were analysed, processing fabrics consecutively decreased the whiteness index, but applying drying operations in between processes increased the whiteness index. And laccase enzyme alone did not have a significant effect on the whiteness index of the fabric.

When we look at the hydrophilicity test results, the hydrophilicity of fabrics was clearly affected in a positive way by the treatment of fabrics with enzymes. And among the three different enzymes used, pectinase enzyme provides the highest hydrophilicity.

The limited application of these enzymes on recycled fabrics in the literature is the innovative aspect of this study, and it is thought that the study will contribute to the literature (Sağır, 2023). In future studies, different enzyme concentrations can be used to investigate the effect of the amount of enzyme used on these properties.

5. Acknowledge

This project was my bachelor graduation project. And i am so happy to work with my dear advisor Prof. Dr. Burcu Yılmaz in this project. This project also could not have been realised without the help of TYH Textile. Therefore, I would like to thank Mr. Mehmet Kaya, General Manager of TYH Textile. and everyone who contributed. I would especially like to thank my esteemed teacher Onur Atak for his unwavering support of my laboratory work.

References

- [1] Hole, G., & Hole, A. S. (2020). Improving recycling of textiles based on lessons from policies for other recyclable materials: A minireview. *Sustainable Production and Consumption*, 42-51. <https://doi.org/10.1016/j.spc.2020.04.005>
- [2] Doba Kadem, F., & Sevgi, R. (2022) Süprem Örme Kumaşlarda Geri Dönüşüm Pamuk Elyaf Oranının Performans Özelliklerine Etkisinin Belirlenmesi. *Çukurova Üniversitesi Mühendislik Fakültesi Dergisi*, 37(3), 609-616.
- [3] Utebay, B., Çelik, P., & Çay, A. (2019), Effects of cotton textile waste properties on recycled fibre quality. *Journal of Cleaner Production*, 222, 29–35. <https://doi.org/10.1016/j.jclepro.2019.03.033>

- [4] Kabir, S., & Koh, J. (2021). Sustainable Textile Processing by Enzyme Applications. *Biodegradation Technology of Organic and Inorganic Pollutants*, 339-366.
- [5] Shen, J., & Smith, E. (2015). Enzymatic treatments for sustainable textile processing. *Sustainable Apparel*, 119-133. <https://doi.org/10.1016/B978-1-78242-339-3.00004-2>
- [6] Sanches R.A., Takamune K.M., Guimarães B.M., Seawright Alonso R., Karam Jr D., Marcicano J.P.P., Sato Duarte A.Y., & Dedini F.G. (2015). Comparative Study of the Characteristics of Knitted Fabrics Produced from Recycled Fibres Employing the Chauvenet Criterion, Factorial Design and Statistical Analysis. *FIBRES & TEXTILES in Eastern Europe*, 23, 19-24.
- [7] Yılmaz, B. (2010). Selülozik Elyaf İçeren Materyallerin Çevre Dostu Yöntemlerle Boyanması. Doktora Tezi, Marmara Üniversitesi, Fen Bilimleri Enstitüsü.
- [8] Sülar, V., & Okur, A. (2005). Kumaşların Duyusal Özelliklerin Belirlenmesinde Kullanılan Subjektif Değerlendirme Yöntemleri. *Tekstil Ve Mühendis*, 12(60), 14-21.
- [9] Sağır, A.A. (2023). Pamuk ve Recycle Dokuma Kumaşların Enzimli ve Enzimsiz ön İşlemlerinin Bitim Performanslarına Etkisinin Araştırılması. Yüksek Lisans Tezi, Bursa Uludağ Üniversitesi, Fen Bilimleri Enstitüsü.