

# Enhancing Elasticity Properties through Finishing Processes and Different Wool Fabric Designs

Mehmet Akin<sup>1</sup>, Tarkan Aydin<sup>1</sup>, Nursema Pala Avci<sup>2</sup>, Emine Dilara Koçak<sup>2</sup>

<sup>1</sup>Design Center, Altinyildiz Textile and Apparel Inc., Tekirdağ, Türkiye

<sup>2</sup>Department of Textile Engineering, Faculty of Technology, Marmara University, Istanbul, Türkiye

Email: mehmet.akin@altinyildiz.com.tr, Tarkan.Aydin@altinyildiz.com.tr, dkocak@marmara.edu.tr, nursema.pala@marmara.edu.tr

**How to cite this paper:** Akin, M., Aydin, T., Pala Avci, N. and Koçak, E.D. (2025) Enhancing Elasticity Properties through Finishing Processes and Different Wool Fabric Designs. *Journal of Textile Science and Technology*, 11, 37-49.

<https://doi.org/10.4236/jtst.2025.112004>

**Received:** February 20, 2025

**Accepted:** May 25, 2025

**Published:** May 28, 2025

Copyright © 2025 by author(s) and Scientific Research Publishing Inc. This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).

<http://creativecommons.org/licenses/by/4.0/>



Open Access

## Abstract

Fabrics are the driving force behind innovative approaches in the textile industry. In the rapidly evolving field of textile technology, innovation begins with different fiber and yarn technologies, continues with design processes during weaving, and is finalized through finishing treatments that give fabrics unique characteristics. The need for diverse designs in fashion trends is one of the key factors driving the textile industry to explore new and innovative appearances. In this study, Wool/Lycra blended yarns and 100% Wool yarns were used to produce fabrics. For warp yarns, 100% Wool yarns were utilized. Three different fabric structures (Plain, Twill 2/1, and Twill 2/2) were manufactured using both wool and wool-Lycra blends. Additionally, a finishing treatment was applied to enhance the elasticity of the fabrics. The study examined the effects of the elasticity-enhancing finishing treatment on the physical properties (tear resistance, tensile strength, seam slippage, abrasion resistance, elongation, permanent elongation, and dimensional stability under steam pressure) and fastness properties of the fabrics based on their blend ratios and fabric structures. The results indicated that the elasticity finishing treatment was particularly effective in 100% Wool fabric structures, with a significant increase in elasticity observed in 100% Wool Twill woven fabrics.

## Keywords

Wool, Finishing, Elasticity, Physical Properties

## 1. Introduction

Wool fabric production is crucial in driving innovation within the textile industry.

Technological advances have enabled the processing and adaptation of wool fabrics for various applications [1]. As a result, wool fabrics can be utilized in both conventional and innovative textile designs. Due to their inherent elasticity, high thermal insulation, and superior moisture management, wool fabrics provide aesthetic appeal, comfort, and durability, making them indispensable in modern textile applications [2].

Sustainability has become a primary focus in contemporary textile manufacturing, with objectives such as reducing carbon emissions, minimizing water consumption, and utilizing recyclable materials [3] [4]. The renewable nature and reusability of wool contribute significantly to waste reduction in the textile sector. Wool's sustainability aspects are critical for minimizing environmental impact, optimizing resource efficiency, and extending product lifespan [5]. Additionally, wool fabrics align with circular economy principles by offering a recyclable and biodegradable material option [6]. Given their compostability and recyclability, wool-based textiles support "zero-waste" strategies [7]. Furthermore, within the slow fashion movement, the preference for durable, high-quality textiles has increased the demand for wool fabrics [8].

Wool fabrics are frequently blended with elastane-based fibers to enhance their natural elasticity and mechanical performance [9]. Although wool inherently exhibits a certain degree of flexibility, various finishing treatments are required to enhance its elastic recovery and resistance to permanent deformation during wear.

Several finishing techniques are employed to enhance wool fabrics' elasticity and mechanical properties. These include elastomeric coatings, resin treatments, and protein modifications, while mechanical approaches such as stretching, steaming, and heat-setting processes are also widely applied [10]. The finishing process plays a critical role in improving elasticity. In wool-Lycra fabrics, thermalization is applied to stabilize elastane fibers, whereas thermal treatment under controlled temperature and humidity conditions is used to modify the elasticity of natural wool fibers. However, these treatments exhibit distinct effects on fabric performance, durability, and comfort properties [11].

This study investigates the comparative performance of wool-Lycra blended fabrics with different woven structures and wool fabrics subjected to natural finishing processes to enhance elasticity. Post-finishing, the fabrics were evaluated for key physical and mechanical properties, including tear strength, tensile strength, seam slippage, elongation and permanent elongation, abrasion resistance, Dimensional Change Against Steam Press A, Dimensional Change Against Steam Press B, and color fastness characteristics. The influence of these finishing treatments on fabric performance was systematically analyzed.

## 2. Experimental

### Materials and Methods

- **Fiber**

In this study, wool fibers were used for the production of both elastane-con-

taining fabrics and non-elastane fabrics. The properties of the wool fibers utilized in fabric production are presented in **Table 1**, while the characteristics of the Lycra fibers used as elastane are detailed in **Table 2**. The tests performed and the corresponding standards applied are listed in **Table 3**.

**Table 1.** Fiber properties.

Parameter	Value
Fibre Fineness ( $\mu$ )	18.3
% CV Micron	18.1
Fiber Length (Hauteur) mm	65.0
% CV	46.8
Barbe Bmm (All-Meter)	79.2
% CV Bmm	35.4
Short Fiber % < 30 mm	14.7
Short Fiber % < 40 mm	23.7
Elongation	16.5
Neps (1 - 3 mm) (Pieces/100g)	6
Vegetable Matter ( $A*1 + B*2 + C*5 + D*17 + E*25$ ) (specks/100g)	19
Oil (%)	0.45
Moisture (%)	13.9

**Table 2.** Properties of elastane fiber.

Property	Value
Fiber, Code, Origin	Elastane (Lycra) 166L TU UK Lycra Company
Linear Density	44 dtex
Breaking Tenacity	0.87 cN/dtex
Elongation at Break	528%
Heat Resistance	180°C - 220°C
Moisture Regain	1% - 1.5%
Modulus Value	0.1 cN/dtex
Characteristics	Combined multifilament, 5 filaments, semi-dull, for core spinning and weaving

**Table 3.** Fiber tests and standards.

Tests	Standards
Fibre Fineness ( $\mu$ )	(Microprojection ASTM D 2130)
% CV Micron	
Fiber Length (Hauteur) Hmm	AL-METER (IWTO-17-85 E)
% CV Hmm	
Barbe Bmm (All-Meter)	

**Continued**

% CV Bmm	
Short Fiber % < 30 mm	
Short Fiber % < 40 mm	
Neps (1 - 3 mm) (Pieces/100g)	
Vegetable Matter (A*1 + B*2 + C*5 + D*17 + E*25) (specks/100g)	ASTM D-1770
Oil (%), Moisture (%)	

• **Yarn and Properties**

Figures 1-3 present the production stages and processes of the yarns used in this study. Table 4 provides the properties of the yarns that were produced, while Table 5 lists the tests that were performed and the corresponding standards.



Figure 1. Tops process—machines diagram.

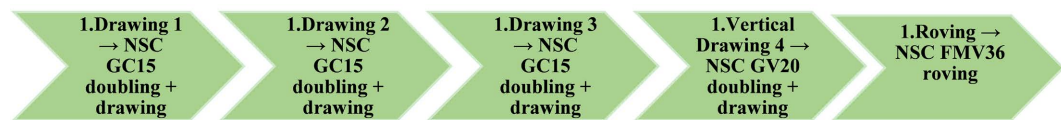


Figure 2. Preparation process—machines diagram.



Figure 3. Spinning and winding process—machines diagram.

Table 4. Yarn properties.

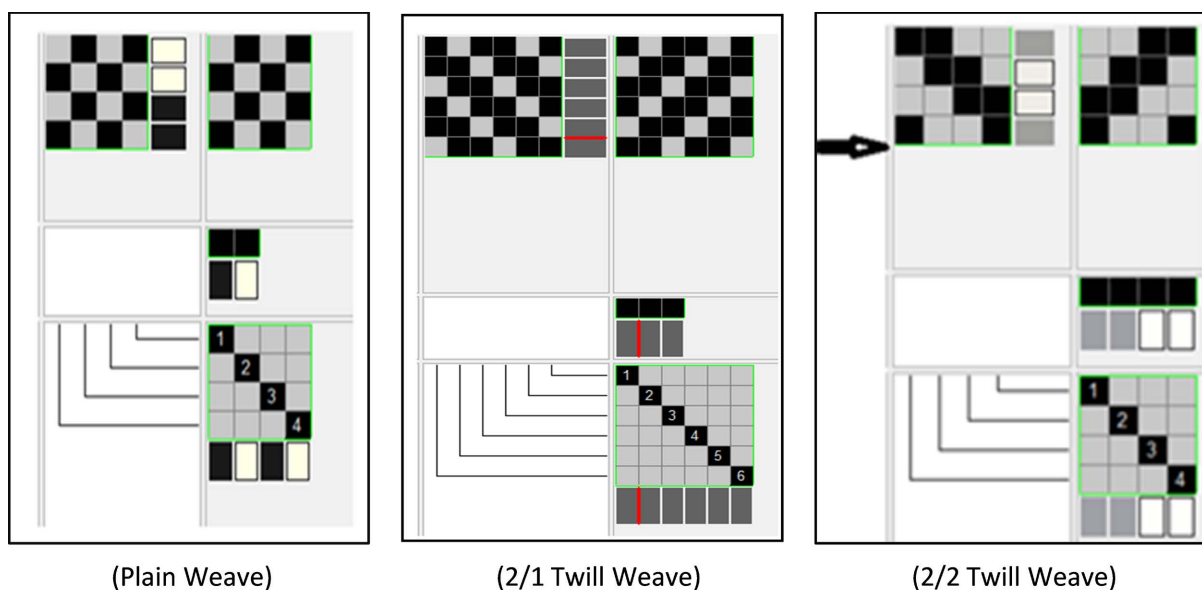
Property	Plain		2/1 Twill		2/2 Twill	
	Warp	Weft	Warp	Weft	Warp	Weft
Yarn Count (Nm)	76	96	48	76	48	76
CV (%)	2.0	1.8	1.7	1.3	2.9	2.0
Twist (T/m)	749	865	842	750	897	750
CV (%)	1.8	0.8	2.2	2.4	2.1	2.0
Strength (cN)	217	171	174	234	161	231
CV (%)	12.4	13.9	12.6	12.6	16.8	17.7
Twist Direction	750 S	850 S	900 Z	750 S	900 Z	750 S
Elongation at Break (%)	20.4	21.8	18.6	24.0	16.6	23.0
CV (%)	34.8	39.9	36.7	33.5	51.9	38.5
Unevenness (Uster %)	11.5	12.9	12.6	11.3	12.6	12.0
Thin Places (-50%) (Per 1000 m)	33	101	99	29	104	58
Thick Places (+50%) (Per 1000 m)	7	28	11	9	16	19
Neps (+200%) (Per 1000 m)	7	18	27	3	15	16
Hairiness (S3-count)	1011	532	1073	753	1425	1300

**Table 5.** Yarn tests and standards.

Property	Method
Yarn Count	TS 244 EN ISO 2060
Twist	TS 247 EN ISO 2061
Breaking Length	TS EN ISO 2062
Strength (cN)	TS EN ISO 2062 Method B
Elongation at Break (%)	TS EN ISO 2062 Method B
Unevenness (Uster %)	TS EN ISO 12947-2
Thin Places (-50%) (Per 1000 m)	TS EN ISO 12947-2
Thick Places (+50%) (Per 1000 m)	TS EN ISO 12947-2
Neps (+200%) (Per 1000 m)	TS EN ISO 12947-2
Hairiness (S3-count)	ASTM D 5647-95

#### • Fabric and Properties

In this study, six different fabrics were created with three different weaving structures. The fabric creation process is shown in **Figure 4**, and the fabric weaving structures are presented in **Figure 5**. The fabric codes and properties are provided in **Table 6**, while the tests and corresponding standards applied to the fabrics are listed in **Table 7**.

**Figure 4.** Fabric creation processes.**Figure 5.** Fabric weaving structures.

**Table 6.** Fabric properties.

Weave Samples	Code	Fabric Weight (g/m <sup>2</sup> )	Fabric Blend (%)	Weft yarn count (Nm)	Warp yarn count (Nm)	Thickness (mm)
Plain Weave	W/L-P	153	96/4 Wool/Lycra	Nm96/2 Siro Wool	Nm76/2 Siro 100% Wool	0.46
Plain Weave	W-P	150	100% Wool	Nm48/1 Wool	Nm76/2 Siro 100% Wool	0.46
2/1 Twill	W/L-T1	182	96/4 Wool/Lycra	Nm96/2 Siro Wool	Nm76/2 Siro 100% Wool	0.65
2/1 Twill	W-T1	178	100% Wool	Nm48/1 Wool	Nm76/2 Siro 100% Wool	0.65
2/2 Twill	W/L-T2	196	96/4 Wool/Lycra	Nm96/2 Siro Wool	Nm76/2 Siro 100% Wool	0.78
2/2 Twill	W-T2	186	100% Wool	Nm48/1 Wool	Nm76/2 Siro 100% Wool	0.78

**Table 7.** Fabric tests and standards.

Tests	Standards
Tear Strength	BS 4303
Tensile Strength	BS 2576
Abrasion Resistance	ISO 12947-2
Seam Slippage	BS 3320
Dimensional Change Against Steam Press (Hoffman Shrinkage-A)	DIN 53894
Dimensional Change Against Steam Press (Hoffman Shrinkage-B)	DIN 53894
Elongation	DUPONT TTM079 A
Permanent Elongation	DUPONT TTM079 A
Colorfastness to washing	ISO 105-C06:2010
Colorfastness	ISO 105-E01:2013
Rubbing fastness	ISO 105-E04:2013
Lightfastness	ISO 105 B02:2014

#### • Finishing Process Applied to Fabrics

To enhance elasticity, finishing treatments were applied to fabrics with three different weaving structures, including Lycra/Wool blend fabrics and 100% wool fabrics, under varying process conditions. The finishing process applied to the fabrics is provided in **Table 8**. The performance of the fabrics was evaluated after the treatment.

**Table 8.** Natural stretch wool fabric design—finishing processes.

Process Steps	Purpose	Natural Stretch Process Conditions (Speed, Temperature, Chemical g/l)	Lycra Process Conditions (Speed, Temperature, Chemical g/l)
Washing (Open Width)	Removing spinning oil and warp wax	70° C, 20 m/min, Soap 1.5 g/l	70° C, 20 m/min, Soap 1.5 g/l

## Continued

<b>Crabbing</b>	Boiling, preventing creases, and balancing internal fabric tensions	95°C - 100°C, 15 m/min	95°C - 100°C, 15 m/min
<b>Fixation (Ram)</b>	Pre-stabilization of Lycra	-	180°C, 35 m/min
<b>Drying (Ram)</b>		130°C, 20 m/min	-
<b>Fabric Dyeing</b>		Yes	Yes
<b>Drying (Ram)</b>		130°C, 25 m/min	130°C, 25 m/min
<b>Gassing Process</b>	Burning surface fuzz	90 m/min	90 m/min
<b>Washing (Open Width)</b>	Removing burnt fibers from the surface	Water only (No chemicals, room temperature)	Water only (No chemicals, room temperature)
<b>Drying (Ram)</b>		130°C, 25 m/min	130°C, 40 m/min
<b>Tweezer Process</b>	Mechanical repair of weaving defects	Yes	Yes
<b>Shearing</b>	Cutting surface fuzz	15 m/min	15 m/min
<b>Thermofixation (Ram)</b>	Lycra stabilization	-	190°C, 20 m/min
<b>Drying (Ram)</b>		130°C, 25 m/min - 10 g/l Silicone	130°C, 25 m/min - 20 g/l Silicone
<b>Continuous Decatizing (Decofast)</b>	Pre-dimensional stabilization, hand feel	20 m/min, reverse process	18 m/min, reverse process
<b>Decatizing (KD-Boiler Decatizing)</b>	Final dimensional stabilization, gloss, hand feel	1.2 bar	1.2 bar
<b>Calendering</b>	Polishing & glossy finish	8 m/min, 0.5 g/l glossy finish, face side	-
<b>Drying (Ram)</b>		130°C, 25 m/min	-
<b>Continuous Decatizing (Decofast)</b>	Pre-dimensional stabilization, hand feel	20 m/min, reverse process	-
<b>Decatizing (KD-Boiler Decatizing)</b>	Final dimensional stabilization, gloss, hand feel	1.2 bar	-
<b>Drying (Ram)</b>		130°C, 25 m/min	130°C, 40 m/min

### 3. Results

The tear strength of the fabrics obtained in this study was evaluated in both the warp and weft directions (See **Figure 6**), with the highest value associated with the W-T2 fabric. The fabrics with the highest tear strength have a 2/2 Twill weave structure. The 2/2 Twill weave structure is looser, which allows the yarns to slide during tear and better distribute the applied load. The yarns used in the 2/2 Twill weave structure are more twisted and thicker than those used in other weave structures, contributing to an increase in tear strength. After the finishing process, tear strength generally shows greater resistance in the warp direction. The thermofixation process has been particularly effective regarding tear strength in the Twill 2/1 and 2/2 fabrics. Following the finishing process, the 100% wool fabrics exhibited higher tear resistance than the Lycra-blended fabrics.

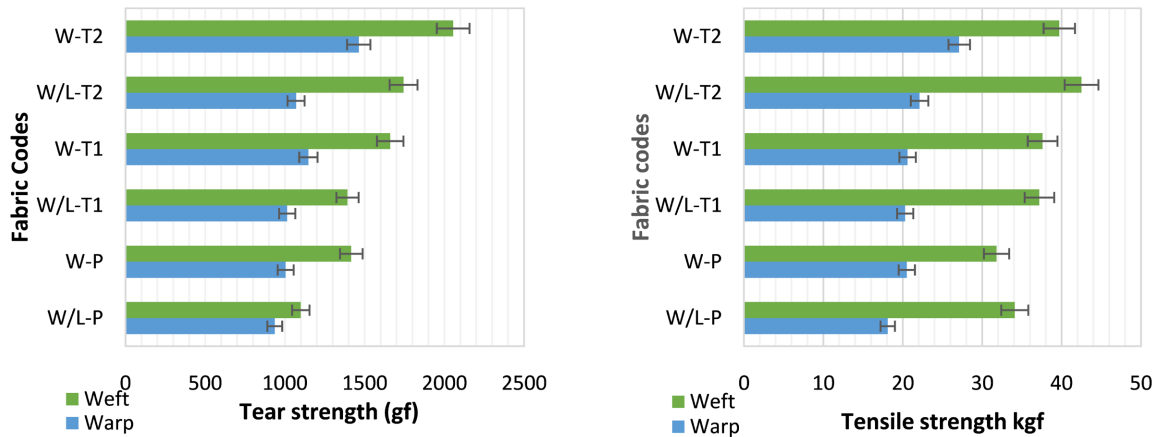


Figure 6. Tear and tensile strength of fabrics.

The tensile strength of the 2/1 and 2/2 Twill woven fabrics is higher compared to plain woven fabrics. Particularly in the 2/2 Twill weave structure, the tensile strength reached 27.1 kgf in the warp direction and 39.7 kgf in the weft direction. The high yarn strength (161 - 234 cm) and twist (750 - 900 T/m) in the 2/2 Twill woven fabrics contribute to the increased tensile strength of the fabric. The break strength of the 100% wool fabrics, which gained natural elasticity through the influence of temperature and chemicals, increased in relation to the dimensional stability of the wool fabrics. Fabrics, particularly those with a 2/2 Twill weave structure, show high tensile strength values after the finishing process.

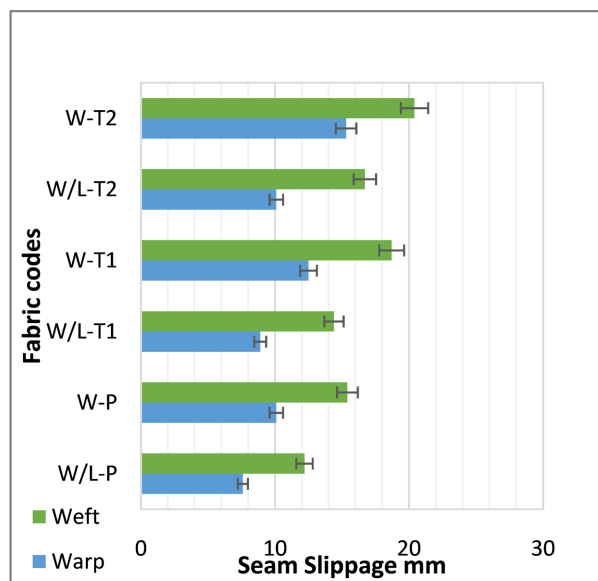
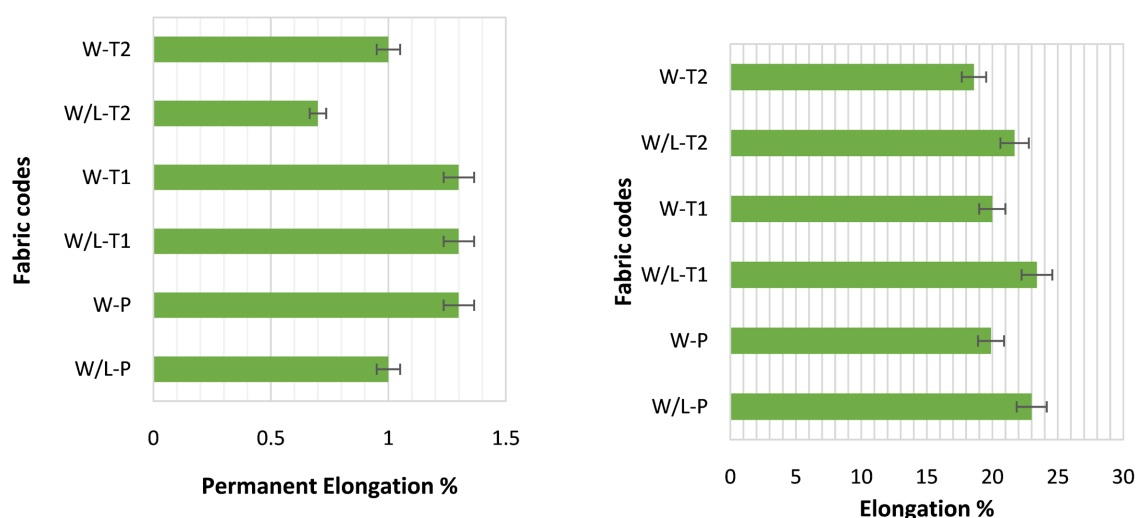


Figure 7. Seam slippage of fabrics.

In Figure 7, the fabrics with the W-T2 weave structure (20.4 mm) and the W-T1 weave structure (18.7 mm) exhibit the highest seam slippage. This situation is generally associated with a looser knit construction and lower yarn twist ratio. The

W/L-P knit fabric shows the lowest seam slippage in the weft direction (12.2 mm). The tight weave structure and high yarn twist ratio prevent the yarns from slipping along the seam. This characteristic provides the fabric structure with more durable and long-lasting properties. The lowest warp strength may result in higher seam slippage after thermofixation, while Lycra stabilization may increase seam slippage.

The W/L-T2 fabric (16.7 mm) and W-P fabric (15.4 mm), along with the W/L-T1 fabric (14.4 mm), exhibit noticeable seam slippage. The connection points in the fabric's knit structure are fewer, so under excessive load and tension, deformation may occur compared to the 2/2 Twill structure fabrics. The 2/2 Twill structure has reduced seam slippage; however, due to Lycra, seam slippage may still occur in the weft direction after thermofixation. The W/L-P fabric (12.2 mm) has the lowest seam slippage in the weft direction. The plain, tightly knitted structure and high yarn twist ratio make seam slippage more difficult. It exhibits the highest seam strength and is minimally affected by thermofixation, maintaining its stability.



**Figure 8.** Elongation and permanent elongation properties of fabrics.

The elongation percentage characteristics of the produced fabrics, as shown in **Figure 8**, demonstrate that Lycra-based fabrics generally exhibit higher elasticity. These fabrics have an elongation rate of 23% to 23.4%, with permanent elongation rates between 1% and 1.3%, indicating that most of the high elasticity is recoverable. For 100% wool fabrics, the elongation rate ranges from 18.6% to 20%, with a permanent elongation rate of 1%. In this case, wool fabrics have lower elasticity. However, with the Twill knitting structure, elasticity is increased, and the permanent elongation rate reaches 21.7% with a 0.7% permanent elongation. Thus, a balance has been achieved in wool fabrics, allowing for permanent elongation without Lycra. After the finishing processes, the Lycra-blended fabrics exhibited a reduction in permanent elongation and an improvement in recovery. The best

balance in permanent elongation was achieved in the Wool-Lycra Twill 2/2 (W/L-T2) fabric.

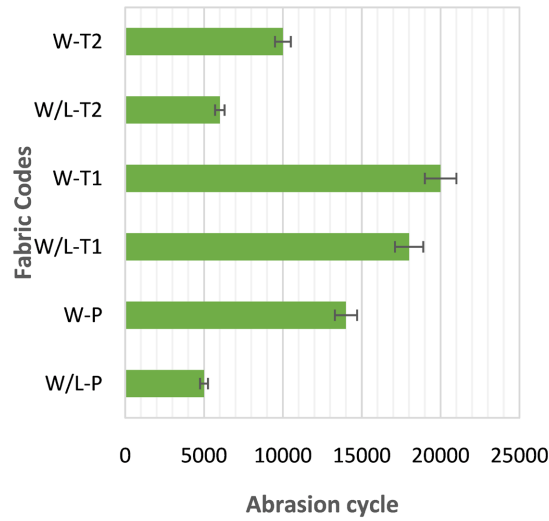


Figure 9. Abrasion cycle properties.

As shown in Figure 9, the abrasion cycle properties exhibited higher durability in the Lycra-based fabrics. When the knitted structures underwent finishing processes and were combined with the Twill weave structure, they became both more flexible and more resistant to abrasion. According to the finishing process results, Twill woven fabrics exhibited higher abrasion resistance compared to plain woven fabrics. While Lycra-containing wool fabrics enhanced their elasticity, they showed a reduction in abrasion resistance. The fabric with the best abrasion resistance was the Wool-Twill 1/1 (W-T1) fabric.

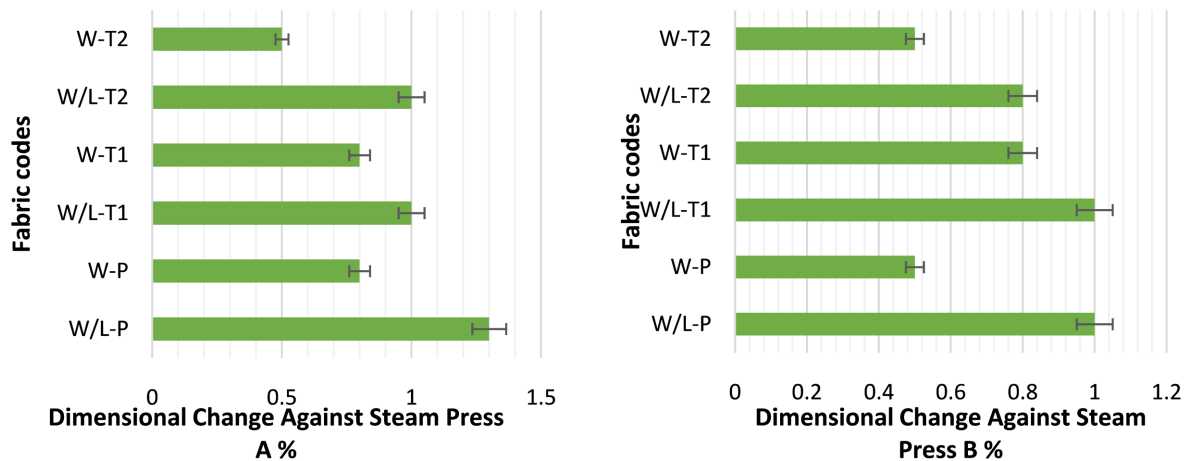


Figure 10. Dimensional change against steam press properties of Lycra-containing wool fabrics.

Figure 10 shows that the fabrics L-P, W/L-T1, and W/L-T2 exhibited greater dimensional changes when pressed with steam. Generally, these fabrics demon-

strated higher flexibility and dimensional changes, but they maintained dimensional stability, with W/L-P showing the most significant changes. Although the Lycra structure provides elasticity to the fabrics, it also limits their dimensional changes. Wool fabrics without Lycra, such as W/P, W-T1, and W-T2, showed less dimensional change. These fabrics, particularly those with the Twill knit structure, exhibited lower dimensional changes during the steam press process. Wool Twill fabrics, such as W-T2, demonstrated highly stable structures with dimensional change rates of 0.5%. Overall, the finishing process improved dimensional stability across all fabrics, with Lycra-containing fabrics showing higher dimensional changes. These alterations promote fiber reorientation, reduce residual stresses, and stabilize the yarns, particularly in Lycra-blended fabrics. These treatments cause a permanent dimensional set, which is a key feature for the performance of tailored garments, where retaining shape and structure is crucial. Although minimal recoverable shrinkage may be observed after further laundering or re-pressing, the majority of the dimensional changes are irreversible, ensuring that the garments maintain their intended fit and structure over time. The best stability was observed in the Wool-Twill 2/2 (W-T2) fabric. The Twill weave structure, combined with finishing processes, contributed to better dimensional stability.

### Fastness Properties

The fastness properties of different fabric types were evaluated based on the factors influencing them after the finishing process. The results of the fastness properties are provided in **Table 9**.

**Table 9.** Fastness properties results.

Material	Washing							Rubbing Fastness		Light Fastness
	Color Change	Staining						Dry	Wet	
		CA	CO	PA	PET	PAN	WO			
W/L-P	4 - 5	4	4	4	4	4 - 5	5	4 - 5	4 - 5	4 - 5
W-P	4	4	4	4	5	4 - 5	5	4	4	4
W/L-T1	4 - 5	4 - 5	4 - 5	4 - 5	4 - 5	4 - 5	4 - 5	4 - 5	4 - 5	4 - 5
W-T1	4 - 5	4	4	5	4 - 5	5	4	4	4 - 5	4 - 5
W/L-T2	4 - 5	4 - 5	5	5	4 - 5	4 - 5	5	5	4 - 5	5
W-T2	4 - 5	5	5	5	4 - 5	5	5	5	5	5

Upon evaluating the washing fastness results, all fabric types exhibit high washing fastness, ranging between 4 - 5. The W-T2 and W/L-T2 fabric types stand out as having the highest washing fastness. Rubbing fastness is around 4 - 5 for all fabric types. The wet rubbing fastness of the W-P and W-T1 fabrics is rated 4, showing slight color loss. Light fastness ranges between 4 and 5 for all fabric types, with the W/L-T2 fabric showing an increase in light fastness. For staining tests against different fiber types, the fastness values are in the 4 - 5 range. The W/T2

and W/L-T2 fabrics achieved the best stain fastness, reaching a level of 5 across all fibers.

#### 4. Conclusions

This study analyzed the mechanical and physical properties of different fabric types after the finishing process. Overall:

- The highest tensile and tearing strength was observed in the Wool-Twill 2/2 (W-T2) fabric.
- The highest abrasion resistance was found in the Wool-Twill 1/1 (W-T1) fabric.
- Wool-Twill 2/2 (W-T2) exhibited the best dimensional stability and the least steam press effect.
- The Wool-Twill 2/2 (W-T2) fabric was the most resistant to seam slippage.
- Regarding elongation, the best values were found in the Wool-Lycra Twill 1/1 (W/L-T1) fabric.
- Wool-containing Lycra fabrics (W/L-P, W/L-T1, W/L-T2) performed well in all fastness tests, showing generally high performance.
- The W/L-T2 fabric demonstrated the highest performance in nearly all categories, indicating that the elasticity treatment did not negatively affect fastness properties, and in some cases, it even improved them.
- The W-P and W-T1 fabrics showed relatively lower wet rubbing fastness, but they generally exhibited acceptable durability.

In conclusion, the Wool-Twill 2/2 (W-T2) fabric demonstrated the best performance in terms of breaking and tearing strength, abrasion resistance, seam slippage, and dimensional stability. Wool/Lycra fabrics stood out for their elastic properties. Finishing treatments, especially on twill structures, positively affected the overall fabric properties.

#### Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

#### References

- [1] Jayalakshmi, I. (2024) Wool-Beyond Fashion Exploring Its Applications in Sustainable Textile Innovations and Functional Fabrics. In: Raj, P., Rocha, A., Dutta, P.K., Fiorini, M. and Prakash, C., Eds., *Information Systems Engineering and Management*, Springer Nature Switzerland, 305-330. [https://doi.org/10.1007/978-3-031-71052-0\\_11](https://doi.org/10.1007/978-3-031-71052-0_11)
- [2] Akcagun, E., Bogusławska-Bączek, M. and Hes, L. (2017) Thermal Insulation and Thermal Contact Properties of Wool and Wool/PES Fabrics in Wet State. *Journal of Natural Fibers*, **16**, 199-208. <https://doi.org/10.1080/15440478.2017.1414650>
- [3] Rahaman, M.T., Pranta, A.D., Repon, M.R., Ahmed, M.S. and Islam, T. (2024) Green Production and Consumption of Textiles and Apparel: Importance, Fabrication, Challenges and Future Prospects. *Journal of Open Innovation: Technology, Market, and Complexity*, **10**, Article 100280. <https://doi.org/10.1016/j.joitmc.2024.100280>
- [4] Din, T.U., Zaman, N., Uddin, M.N., Khan, W., Qayum, N., Qayum, S., *et al.* (2025)

- The Circular Economy Concept in the Textile Industry. In: Arshad, M., Ed., *SDGs and Textiles*, Springer Nature Singapore, 331-361.  
[https://doi.org/10.1007/978-981-97-8058-7\\_13](https://doi.org/10.1007/978-981-97-8058-7_13)
- [5] Malabadi, R.B., Kolkar, K.P., Chalannavar, R.K. and Baijnath, H. (2025) Plant-Based Leather Production: An Update. *World Journal of Advanced Engineering Technology and Sciences*, **14**, 31-59. <https://doi.org/10.30574/wjaets.2025.14.1.0648>
- [6] Wiedemann, S.G., Biggs, L., Nebel, B., Bauch, K., Laitala, K., Klepp, I.G., et al. (2020) Environmental Impacts Associated with the Production, Use, and End-of-Life of a Woollen Garment. *The International Journal of Life Cycle Assessment*, **25**, 1486-1499. <https://doi.org/10.1007/s11367-020-01766-0>
- [7] Younus, M. (2025) The Economics of a Zero-Waste Fashion Industry: Strategies to Reduce Wastage, Minimize Clothing Costs, and Maximize Sustainability. *Strategic Data Management and Innovation*, **2**, 116-137. <https://doi.org/10.71292/sdmi.v2i01.15>
- [8] Sarokin, S.N. and Bocken, N.M.P. (2024) Pursuing Profitability in Slow Fashion: Exploring Brands' Profit Contributors. *Journal of Cleaner Production*, **444**, Article 141237. <https://doi.org/10.1016/j.jclepro.2024.141237>
- [9] Doifode, C. (2023) Chemical Recycling of Elastane and Elastane Blends. Master's Thesis, Norwegian University of Science and Technology.
- [10] de Oliveira, C.R.S., da Silva Júnior, A.H., Ferreira, A.J.S., Immich, A.P.S. and Lopes, T.J. (2024) Treatments on Wool and Structural Evaluation. In: Sadasivan, S.M., et al., Eds., *Handbook of Natural Polymers*, Volume 2, Elsevier, 177-204. <https://doi.org/10.1016/b978-0-323-99856-7.00006-9>
- [11] Bilen, U. and Yasar, Y. (2024) Investigating the Effect of Elastane Use on Tailorability and Appearance of Wool and Wool Blend Suiting Fabrics. *Journal of Natural Fibers*, **21**, Article 2299685. <https://doi.org/10.1080/15440478.2023.2299685>