A Comparative Study on Selected Properties of Post-Dyed Spandex-Blended Interlock Knitted Fabrics Produced from Virgin and Recycled PA6 Yarns

Tho Luu Thi
Faculty of Garment Technology and Fashion Design, Hanoi University of Industry, Hanoi, Vietnam
tholt@haui.edu.vn (corresponding author)

Mai Nguyen Thi
Faculty of Garment Technology and Fashion Design, Hanoi University of Industry, Hanoi, Vietnam
mai_tktt@haui.edu.vn

Hai Nguyen Van
Faculty of Garment Technology and Fashion Design, Hanoi University of Industry, Hanoi, Vietnam
hainguyen@haui.edu.vn

Received: 17 February 2026 | Revised: 19 April 2026 | Accepted: 26 April 2026

ABSTRACT

This study presents a controlled comparative evaluation of selected properties of post-dyed interlock-knitted fabrics produced from virgin and recycled PA6/spandex yarns under nominally matched structural and wet-processing conditions. To reduce the influence of major structural variables, the two fabrics were prepared with the same nominal interlock structure, blend ratio, yarn linear density, and dyeing and finishing route. The investigation included a comparison of basic structural parameters, FTIR absorption bands, strip-test elasticity-related behavior, dimensional change after laundering, and water-absorption performance. The results showed that the two fabrics had nearly identical mass per unit area, thickness, course density, and wale density before performance testing. FTIR analysis confirmed that the main characteristic absorption bands of polyamide remained detectable in both samples after dyeing. Under the investigated conditions, the recycled Polyamide 6 (PA6) fabric exhibited lower maximum force and elastic recovery, but higher extension and permanent deformation, as well as higher washing shrinkage and a shorter water-absorption time than the corresponding virgin PA6 fabric. These findings indicate that the two material systems did not exhibit equivalent post-dyeing behavior but instead showed different balances of mechanical resilience, dimensional stability during laundering, and wetting behavior. The main contribution of this study lies in the side-by-side evaluation of chemical signature, elasticity-related behavior, laundering dimensional change, and wetting performance in post-dyed PA6/spandex interlock fabrics produced from virgin and recycled PA6 yarns under nominally matched conditions. Within the scope of this controlled two-sample comparison, the study provides comparative evidence on the technical feasibility of recycled PA6 in spandex-blended interlock fabrics and clarifies the associated property trade-offs.

Keywords-polyamide 6; recycled polyamide 6; interlock knitted fabric; spandex; elastic recovery

I. INTRODUCTION

Polyamide 6 (PA6) is widely used in textile applications because of its favorable combination of mechanical strength, abrasion resistance, elasticity, and processing performance [1, 4]. Among weft-knitted structures, interlock fabrics are commonly preferred because of their compact construction, smooth surface appearance, and relatively good dimensional stability [1, 2]. When blended with spandex, PA6-based knitted fabrics can provide enhanced stretch, fit, and wearer comfort, making them suitable for sportswear, intimate apparel, and other close-fitting garments. In these fabrics, elasticity-related behavior is governed not only by the elastane component but also by the properties of the accompanying yarn and the knitted structure itself [2, 3]. Increasing concerns regarding fossil resource consumption and textile waste have accelerated interest in recycled synthetic fibers [4]. Depending on the recycling method and prior processing history, recycled polyamide may exhibit changes in physical and mechanical properties that can influence its performance in textile applications [5, 6]. As a result, recycled polyamide has attracted considerable attention as a potential alternative to virgin PA6 in textile products [4, 7, 8]. Polyamide recycling can be achieved through several approaches, including mechanical recycling, chemical recycling, and selective dissolution processes [4, 9, 10]. These considerations are particularly important in stretch knitted fabrics, where extension and recovery behavior, dimensional stability during laundering, and moisture-management performance contribute to end-use functionality.

In PA/spandex textile systems, interpretation becomes more complex because the final fabric behavior is governed by the combined response of the polyamide and spandex phases, and the knitted structure. Previous studies on nylon/spandex materials have mainly focused on recycling routes, spandex removal, or material recovery from blended textile wastes [8, 11-13]. Elastic behavior, dimensional stability, or dyeing-related characteristics of polyamide-containing textile materials have also been examined [2, 3, 14]. Nevertheless, direct side-by-side comparisons between post-dyed interlock knitted fabrics produced from virgin PA6/spandex and recycled PA6/spandex yarns under nominally similar structural and wet-processing conditions remain limited. Therefore, the present work was designed as a controlled comparative study of selected properties of post-dyed interlock knitted fabrics produced from virgin and recycled PA6 yarns blended with spandex. The two fabric variants were prepared with the same nominal interlock structure, blend ratio, yarn linear density, and dyeing and finishing route to reduce the influence of major structural and processing variables. FTIR analysis was used to compare the main characteristic absorption bands of the polyamide component after dyeing. In contrast, elasticity-related behavior, washing shrinkage, and water absorption were measured to evaluate differences in fabric performance. Within the scope of this study, the objective was not to establish a single, strict mechanistic cause, but rather to compare the performance tendencies of two specific post-dyed interlock fabric systems prepared under controlled conditions. The novelty of this work lies in the side-by-side evaluation of chemical signature, elasticity-related behavior, dimensional change after laundering, and wetting behavior in matched post-dyed PA6/spandex interlock systems produced from virgin and recycled polyamide yarns.

II. MATERIALS AND METHODS

A. Materials

As shown in Table I, two interlock knitted fabric samples were used in this study. Sample M1 was produced from virgin PA6/spandex yarn, whereas sample M2 was produced from recycled PA6/spandex yarn. In both samples, the nominal blend ratio was 75/25. The virgin PA6 yarn used in M1 was a filament yarn with a specification of 70/68, corresponding to a fineness of 70 denier, composed of 68 individual filaments. The recycled PA6 yarn used in M2 had the same nominal yarn fineness. The recycled material was a pre-consumer recycled polyamide supplied by Jiangsu Yueyuan Fiber Technology Co., Ltd. The spandex component in both fabrics had a yarn fineness of 40 denier. The interlock structure was selected for its stable geometry, smooth surface, and relatively good dimensional behavior, making it suitable for comparative evaluation.

TABLE I. BASIC STRUCTURAL PARAMETERS OF THE EXPERIMENTAL FABRICS

Parameter	M1 (PA6/spandex)	M2 (rPA6/spandex)
Blend ratio (%)	75% PA6, 25% spandex	75% rPA6, 25% spandex
Knit structure	Interlock	Interlock
Polyamide yarn linear density	70D	70D
Spandex yarn linear density	40D	40D
Fabric mass per unit area (g/m²)	220.2	220.0
Course density (loops/100 mm)	41	41
Wale density (loops/100 mm)	25	25
Thickness (mm)	0.81	0.81

B. Chemicals and Dyeing-Finishing Procedure

The chemicals used in the dyeing process included a wetting agent, a leveling agent, acid dyes, acetic acid, sodium carbonate, a color-fixing agent, and neutral soap. The acid dyes were selected for compatibility with polyamide fibers during exhaust dyeing. The dyeing auxiliaries comprised a wetting agent (1 g/L), a leveling agent (1% owf), acetic acid (0.1229%), Na_2CO_3 (0.5%), a color-fixing agent (3% owf), and neutral soap (1 g/L). The fabric samples were dyed by the exhaust dyeing method using a laboratory beaker dyeing machine at a liquor ratio of 1:12. The dye bath pH was adjusted to 4.5–5.5 with acetic acid. The temperature was then raised to 98°C and held for 30 min to complete dyeing. After dyeing, the fabrics were treated with Na_2CO_3 at 75°C for 15 min, followed by washing with neutral soap at 75°C. A mild acid treatment was then carried out at 40°C, followed by treatment with the color-fixing agent and final drying at 80°C. The same dyeing and post-dyeing procedures were applied to both fabric variants to maintain comparability between the two material systems.

C. Evaluation Methods

Before testing, all samples were conditioned in the standard atmosphere for conditioning and testing of textiles in accordance with [15] (20 ± 2°C and 65 ± 4% relative humidity). Fabric mass per unit area, course density, and wale density were determined in accordance with [16, 17]. Fabric thickness was measured and reported, along with the structural parameters, as depicted in Table I, and the equipment used in this study is presented in Table II. Fourier transform infrared spectroscopy was carried out using a Jasco 6300 FTIR spectrophotometer. The analysis focused on the main characteristic absorption bands of polyamide, including N–H stretching, C–H stretching, Amide I, and Amide II, to compare the chemical signatures of PA and rPA fibers after dyeing. In the present study, FTIR was used as a comparative tool to confirm whether the principal characteristic bands of polyamide remained detectable in both samples after dyeing.

Elasticity-related properties were determined using the strip-test method in accordance with [18]. Five specimens were tested for each fabric variant under the same specimen preparation and loading conditions. The reported parameters were maximum force under the selected strip-test conditions, extension, permanent deformation after 1 min, and elastic recovery. Dimensional change after laundering was evaluated in accordance with [19]. The laundering procedure followed the 3N with tumble drying D1 [20] procedure, and three wash-dry cycles were applied. The longitudinal and widthwise dimensional changes are reported as washing shrinkage in this study. Water absorption was measured according to [21] using the drop method. Five specimens of approximately 200 mm × 200 mm were tested for each fabric variant. A 0.1 mL drop of water was released from a burette positioned 10 mm above the specimen surface, and the absorption time was recorded from the first contact until no visible free water remained on the surface. Each test was repeated five times, and the mean value was calculated. Because the present work was designed as a controlled comparative study involving only two fabric variants, the analysis is limited to the observed performance tendencies under the specific material and processing conditions examined. No inferential statistical testing was conducted in the present study; therefore, the reported differences should be interpreted as comparative tendencies observed under the investigated conditions.

TABLE II. MAIN EQUIPMENT USED IN THE STUDY

No.	Equipment	Model / description	Application
1	Electronic balance	Laboratory balance	Measurement of specimen mass
2	Laboratory dyeing machine	GT-D22B	Exhaust dyeing of fabric samples
3	Water absorption tester	Wetting/absorption tester	Measurement of water absorption
4	Fabric dryer	GT-D10	Drying of samples after dyeing
5	FTIR spectrophotometer	Jasco 6300	Analysis of chemical structure
6	Tensile tester	Laboratory tensile testing device	Measurement of tensile and recovery properties

III. RESULTS AND DISCUSSION

A. Structural Comparability of the Two Fabrics

As shown in Table I, the two fabrics had nearly identical basic structural parameters, including mass per unit area, course density, wale density, and thickness. This structural similarity is important because it reduces, though it does not eliminate, the influence of major fabric-geometry differences on subsequent performance comparisons. Accordingly, the differences discussed below are interpreted as differences between two specific post-dyed PA6/spandex interlock systems prepared under nominally matched structural and processing conditions, rather than as proof that fiber origin alone is the sole governing factor.

B. Comparative FTIR Results

The main FTIR absorption bands of the PA and rPA fibers are summarized in Table III. The characteristic absorption bands of the two samples were very close in position. In both cases, the N–H stretching, C–H stretching, Amide I, and Amide II bands remained detectable after dyeing, indicating that the principal chemical signature of polyamide was retained in the recycled material under the conditions examined. This observation is consistent with [14], which reported that recycled PA6 retained its characteristic FTIR features after dyeing. It is also generally consistent with broader studies on polyamide recycling, which suggest that recycling may affect performance without completely removing the principal chemical functionality of the polyamide backbone [4–6]. In the present study, the FTIR results therefore support the view that the differences observed in the subsequent performance tests were not associated with a major loss of the characteristic polyamide groups. At the same time, this interpretation should remain limited. FTIR confirms the presence of the main functional groups, but it does not directly determine molecular weight, crystallinity, or surface morphology. Therefore, the FTIR data in this study are used as comparative chemical evidence rather than as direct mechanistic proof of the origin of the observed differences in strip-test behavior, washing shrinkage, or water absorption.

TABLE III. MAIN FTIR ABSORPTION BANDS OF VIRGIN AND RECYCLED PA6 FIBERS AFTER DYEING

Band assignment	PA (cm^{-1})	rPA (cm^{-1})	Interpretation	Observation
N-H stretching	3291.97	3292.14	Hydrogen-bond-related amide group	Nearly identical
C-H stretching	2928.03 / 2859.82	2928.44 / 2860.51	Hydrocarbon chain vibration	Very similar
Amide I (C=O stretching)	1628.39	1628.13	Characteristic polyamide carbonyl band	Preserved
Amide II (N-H bending/C-N stretching)	1531.69	1531.65	Peptide bond signature	Preserved

C. Comparative Elasticity-Related Behavior

1) Maximum Force, Extension, Permanent Deformation, and Elastic Recovery

The strip-test results are presented in Table IV. Compared with M1, the fabric produced from recycled PA6/spandex yarn (M2) showed lower maximum force, but higher extension, higher permanent deformation after 1 min, and lower elastic recovery. Under the test conditions used, these results indicate that M2 was more readily deformed during the selected strip-test program and showed a lower tendency to recover its original dimensions after unloading. In stretch knitted fabrics, extension and recovery behavior are governed by the combined effects of yarn properties, loop geometry, and the elastic contribution of the elastane component [2, 3]. Since both fabrics had the same nominal blend ratio, the same nominal yarn linear density, and nearly identical basic structural parameters, the observed difference is reasonably attributed to differences between the two PA6 yarn systems used in the study. The lower maximum force and weaker recovery of M2 are also consistent with previous studies showing that recycling may alter the physical and mechanical behavior of polyamides through degradation-related changes in the material state [4-6]. Nevertheless, the interpretation should remain cautious. The present study did not include direct measurements of molecular weight, crystallinity, or morphology. Therefore, the results should be described primarily as a comparative difference in performance between the two investigated material systems rather than as conclusive evidence of a specific degradation mechanism. Within the scope of this study, the recycled-PA6 fabric showed lower resistance to the selected strip-test loading program but higher deformability than the corresponding virgin-PA6 fabric.

TABLE IV. MAXIMUM FORCE, EXTENSION, PERMANENT DEFORMATION AFTER 1 MIN, AND ELASTIC RECOVERY OF THE FABRICS

Fabric type	M1 (PA/spandex)	M2 (rPA/spandex)
Maximum force (cN)	800	700
Extension (%)	3	4.5
Permanent deformation after 1 min (%)	1.5	2.5
Elastic recovery (%)	90	80

2) *Washing Shrinkage*

The washing shrinkage results are summarized in Figure 1. The recycled-PA6 fabric exhibited greater shrinkage in both the longitudinal and widthwise directions than the virgin-PA6 fabric. Specifically, the longitudinal shrinkage increased from 1.5% for the PA/spandex fabric to 2% for the rPA/spandex fabric, while the widthwise shrinkage increased from 0.5% to 1%. Under the laundering conditions used in this study, M2 therefore underwent greater dimensional change after washing than M1. This behavior may be discussed in relation to elastane-containing interlock fabrics, in which shrinkage is affected by loop relaxation, stitch retraction, and the recovery behavior of the elastic components [2, 3]. Since both fabrics were produced with the same nominal knitted structure and blend composition, the higher shrinkage observed for M2 suggests that the recycled-PA6 system responded differently during post-wash relaxation. However, the results should be interpreted cautiously. The present study did not include direct measurements of residual stress, relaxation kinetics, or polymer morphology, and therefore cannot provide a definitive explanation for the higher shrinkage of M2. Within the investigated conditions, the findings indicate that the two fabric systems exhibited different dimensional responses during laundering. The recycled-PA6 fabric showed greater washing shrinkage, whereas the virgin-PA6 fabric demonstrated higher recovery in the strip-test assessment. These observations are directionally consistent and suggest that the virgin-PA6 fabric possessed greater dimensional resilience under the investigated conditions.

3) *Water Absorption*

The water absorption results are presented in Figure 2. The fabric produced from recycled PA6/spandex yarn exhibited a shorter absorption time than the fabric produced from virgin PA6/spandex yarn, decreasing from 80 s to 66 s. Under the selected test method, the shorter absorption time indicates faster wetting behavior of the recycled-PA6 fabric. Because the two fabrics were prepared with nominally similar structural parameters, the observed difference is more reasonably associated with the yarn system than with major differences in fabric construction. In knitted fabrics, liquid uptake is influenced by both fiber-related characteristics and capillary transport through the porous structure [2]. In addition, it has been shown that recycled PA6 remains processable and dyeable after recycling [14], supporting the practical plausibility of altered wetting behavior in recycled polyamide systems. Nevertheless, the interpretation should remain conservative. The present study did not include measurements of contact angle, porosity, or surface morphology, and thus cannot establish the specific mechanism responsible for the faster absorption observed in M2. Within the investigated interlock system, the recycled-PA6 fabric demonstrated faster water absorption than the corresponding virgin-PA6 fabric. Any mechanistic explanation beyond this comparative observation should be considered tentative.

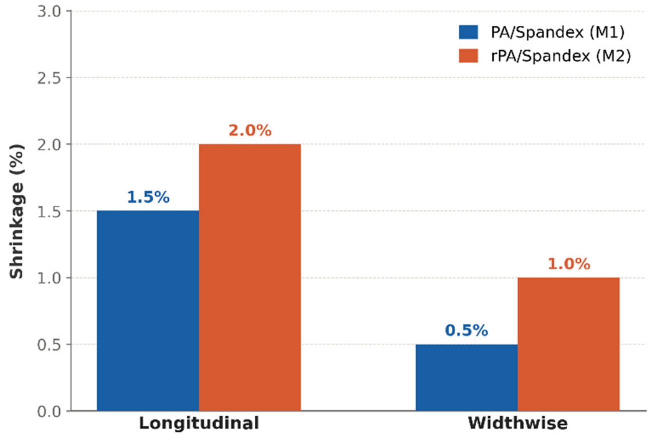

Fig. 1. Washing shrinkage of the fabrics in the longitudinal and horizontal directions.

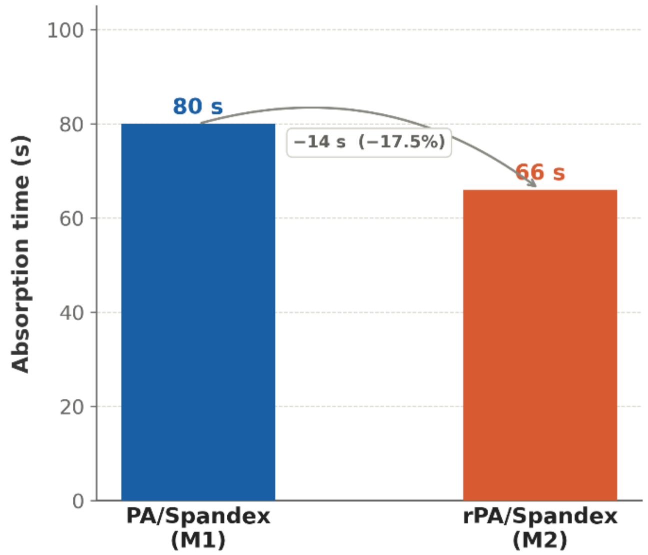

Fig. 2. Water absorption time of the fabrics.

D. Overall Discussion

Taken together, the results indicate that the two post-dyed interlock PA6/spandex fabric systems investigated in this study exhibited different balances of properties. Compared with the fabric produced from virgin PA6/spandex yarn, the fabric produced from recycled PA6/spandex yarn showed lower maximum force and elastic recovery, but higher extension, higher permanent deformation, higher washing shrinkage, and faster water absorption. From an application standpoint, these findings suggest a trade-off rather than a simple superiority of one material over the other. Within the experimental system examined in this work, the virgin-PA6 fabric demonstrated a more favorable response in terms of maximum force, elastic recovery, and dimensional stability during laundering, whereas the recycled-PA6 fabric exhibited faster wetting behavior. These findings indicate that substituting virgin PA6 with recycled PA6 in post-dyed interlock fabrics blended with spandex is technically feasible within the investigated system, but it results in a different property profile rather than equivalent performance. At the same time, the practical implications of these findings should remain within the limits of the present study. Only one recycled-polyamide source, one blend ratio, one nominal yarn fineness, and one knit structure were examined. Therefore, the present results should be understood as comparative evidence for the investigated fabric system under the selected processing conditions, rather than as a broad generalization for all virgin and recycled PA6 knitted fabrics.

IV. CONCLUSIONS

This study presented a controlled comparative investigation of post-dyed interlock knitted fabrics produced from virgin Polyamide 6 (PA6)/spandex and recycled PA6/spandex yarns under nominally matched structural and wet-processing conditions. The work covered material selection, dyeing-finishing under a single process route, verification of structural comparability, comparative FTIR assessment, strip-test evaluation of elasticity-related behavior, dimensional changes after laundering, and water-absorption testing. In this way, the study assessed not only the key performance results but also the experimental context needed to interpret the differences between the two fabric systems. The results showed that the two fabrics had nearly identical basic structural parameters, which supported a direct comparison within the investigated interlock system. FTIR analysis confirmed that the principal characteristic absorption bands of polyamide remained detectable in both samples after dyeing. Under the investigated conditions, the recycled-PA6 fabric exhibited lower maximum force and elastic recovery, but higher extension and permanent deformation, together with higher washing shrinkage and shorter water-absorption time than the corresponding virgin-PA6 fabric. These findings indicate that the two material systems did not behave equivalently after dyeing, but instead showed different balances of mechanical resilience, dimensional response during laundering, and wetting behavior.

The main novelty and contribution of this work lie in the side-by-side evaluation of chemical signature, elasticity-related behavior, laundering dimensional change, and wetting performance in post-dyed PA6/spandex interlock fabrics produced from virgin and recycled PA6 yarns under nominally matched conditions. This integrated comparison provides application-relevant evidence that recycled PA6 is technically feasible in spandex-blended interlock fabrics and clarifies the property trade-offs associated with replacing virgin PA6 with recycled PA6. From a practical standpoint, the virgin-PA6 fabric showed a more favorable response in terms of maximum force, recovery, and dimensional stability after laundering, whereas the recycled-PA6 fabric showed faster wetting behavior. At the same time, the present conclusions should be interpreted within the limits of the experimental design, which included only one recycled-polyamide source, one blend ratio, one nominal yarn fineness, one knit structure, and no inferential statistical testing. Further studies incorporating a broader range of recycled sources, knit structures, and physicochemical characterization methods are proposed to strengthen generalization.

DECLARATION OF COMPETING INTERESTS

The authors declare no competing interests.

ACKNOWLEDGMENT

The authors would like to express their sincere gratitude to Hanoi University of Industry for its support and financial funding for this research. The research team also extends its heartfelt thanks to Best Pacific Vietnam Co., Ltd. for its technical support, which contributed significantly to the implementation and completion of the experimental aspects of this study.

DATA AVAILABILITY

The data that support the findings of this study are not publicly available but may be shared upon reasonable request to the corresponding author.

FUNDING SOURCES

This research was funded by project No. 28-2005-RD, Hanoi University of Industry (HaUI).

AI USE AND DECLARATION OF GENERATIVE AI USE

Generative AI tools were used solely for grammar and spelling assistance during the preparation of this manuscript. All scientific content, analyses, and conclusions were developed entirely by the authors, who take full responsibility for the integrity of the work.

REFERENCES

[1] D. J. Spencer, Knitting Technology: A Comprehensive Handbook and Practical Guide. CRC Press, 2001.

[2] C. N. Herath, B. C. Kang, and H.-Y. Jeon, "Dimensional stability of cotton-spandex interlock structures under relaxation," *Fibers and Polymers*, vol. 8, no. 1, pp. 105–110, Jan. 2007, https://doi.org/10.1007/BF02908167.

[3] T. Jovanović, Ž. Penava, and Z. Vrljičak, "Impact of the Elastane Percentage on the Elastic Properties of Knitted Fabrics under Cyclic Loading," *Materials*, vol. 15, no. 19, Sept. 2022, https://doi.org/10.3390/ma15196512.

[4] V. Hirschberg and D. Rodrigue, "Recycling of polyamides: Processes and conditions," *Journal of Polymer Science*, vol. 61, no. 17, pp. 1937–1958, 2023, https://doi.org/10.1002/pol.20230154.

[5] I. B. Amor, O. Klinkova, M. Baklouti, R. Elleuch, and I. Tawfiq, "Mechanical Recycling and Its Effects on the Physical and Mechanical Properties of Polyamides," *Polymers*, vol. 15, no. 23, Nov. 2023, https://doi.org/10.3390/polym15234561.

[6] P. P. X. Yap, Z. Yen, T. Salim, H. C. A. Lim, C. K. Chung, and Y. M. Lam, "The impact of mechanical recycling on the degradation of polyamide," *Polymer Degradation and Stability*, vol. 225, July 2024, Art. no. 110773, https://doi.org/10.1016/j.polymdegradstab.2024.110773.

[7] R. B. Baloyi, O. J. Gbadeyan, B. Sithole, and V. Chunilall, "Recent advances in recycling technologies for waste textile fabrics: a review," *Textile Research Journal*, vol. 94, no. 3–4, pp. 508–529, Feb. 2024, https://doi.org/10.1177/00405175231210239.

[8] P. Chavez-Linares, S. Hoppe, and I. Chevalot, "Recycling and Degradation Pathways of Synthetic Textile Fibers such as Polyamide and Elastane," *Global Challenges*, vol. 9, no. 4, 2025, Art. no. 2400163, https://doi.org/10.1002/gch2.202400163.

[9] C. Alberti, R. Figueira, M. Hofmann, S. Koschke, and S. Enthaler, "Chemical Recycling of End-of-Life Polyamide 6 via Ring Closing Depolymerization," *ChemistrySelect*, vol. 4, no. 43, pp. 12638–12642, 2019, https://doi.org/10.1002/slct.201903970.

[10] G. Tonsi *et al.*, "Polyamide recycling by selective dissolution approach: Life Cycle Assessment study and environmental impacts comparison with different recycling technologies," *Polymer Engineering & Science*, vol. 65, no. 2, pp. 765–782, 2025, https://doi.org/10.1002/pen.27041.

[11] M. Zhu, C. Gao, S. Wang, S. Shi, M. Zhang, and Q. Su, "Recycling of Spandex: Broadening the Way for a Complete Cycle of Textile Waste," *Sustainability*, vol. 17, no. 8, Apr. 2025, https://doi.org/10.3390/su17083319.

[12] Y. Yin, D. Yao, C. Wang, and Y. Wang, "Removal of spandex from nylon/spandex blended fabrics by selective polymer degradation," *Textile Research Journal*, vol. 84, no. 1, pp. 16–27, Jan. 2014, https://doi.org/10.1177/0040517513487790.

[13] F. Lv, D. Yao, Y. Wang, C. Wang, P. Zhu, and Y. Hong, "Recycling of waste nylon 6/spandex blended fabrics by melt processing," *Composites Part B: Engineering*, vol. 77, pp. 232–237, Aug. 2015, https://doi.org/10.1016/j.compositesb.2015.03.038.

[14] B. S. Metwally, S. A. Rashed, M. N. El-Sheikh, and A. S. Hamouda, "Dyeing of Recycled Electrospun Polyamide 6 Nanofibers: Implications of Dye Particle Size," *Fibers and Polymers*, vol. 24, no. 5, pp. 1681–1693, May c, https://doi.org/10.1007/s12221-023-00165-0.

[15] ISO 139:2005 Textiles — Standard atmospheres for conditioning and testing. Switzerland: International Standard, 2005.

[16] TCVN 5793 - 1994 VẢI DỆT KIM - PHƯƠNG PHÁP XÁC ĐỊNH KHỐI LƯỢNG. Vietnam: VIETNAMESE STANDARDS, 1994.

[17] TCVN 5794 - 1994 VẢI VÀ SẢN PHẨM DỆT KIM PHƯƠNG PHÁP XÁC ĐỊNH MẬT ĐỘ. Vietnam: VIETNAMESE STANDARDS, 1994.

[18] ISO 20932-1:2018 Textiles — Determination of the elasticity of fabrics. Switcherland: International Standard, 2018.

[19] ISO 5077 Textiles — Determination of dimensional change in washing and drying. Switzerland: International Standard, 2007.

[20] ISO 6330 Textiles — Domestic washing and drying procedures for textile testing. Switzerland: International Standard, 2021.

[21] JIS L 1907:2010 Testing methods for water absorbency of textiles. Japan: Japanese Standards Association, 2010.