Asia-Pacific Journal of Science and Technology: Volume: 31 Issue: 06 Article ID: APST-31-06-09 Research Article

APST

Asia-Pacific Journal of Science and Technology

https//:www.tci-thaijo.org/index.php/APST/index

Published by Research and Innovation Department,
Khon Kaen University, Thailand

Mechanical Properties of Cotton/Wool Waste Blends produced from Needle Felting

Krailerck Visesphan [1*], Jirawat Vongphantuset [1] and Eakachat Joenurairatana [1]

[1] Faculty of Decorative Arts, Silpakorn University, Bangkok 10200, Thailand
[*]Corresponding author: visesphan_k@su.ac.th

Received 4 November 2025
Revised 24 June 2026
Accepted 3 July 2026

Abstract

Textile manufacturing produces a large amount of pre-consumer waste, which contributes to environmental challenges. This research explored how discarded cotton and wool fibers can be turned into usable fabrics via the needle-felting method, a dry process that uses barbed needles to interlock fibers without water or chemicals. The cotton offcuts were collected from a weaving factory in Bangkok that produces about 10 kilograms each day, while the wool waste was obtained from a weaving community in Mae Hong Son, Thailand, where about 1,200 kilograms of raw wool are processed per cycle, and nearly one-third ends up as waste. The study examined the effect of three blend ratios: 80% Cotton/20% Wool, 50% Cotton/50% Wool, and 20% Cotton/80% Wool. The fibers were double-carded and then processed by needle felting. The resulting non-woven fabrics were tested for thickness, tensile strength, elongation, tearing resistance, and abrasion mass loss. The findings showed that increasing the wool content yielded thicker fabrics with higher strength and elongation, largely due to the crimped and elastic structure of the wool fibers. In contrast, blends with more cotton content exhibited better dimensional stability and lost less mass under abrasion. Among the samples, the 20% Cotton/80% Wool blend showed the best performance in strength and elasticity, while the 80% Cotton/20% Wool blend was the most resistant to surface wear. Overall, the study demonstrated that needle felting can provide a practical way to repurpose textile waste by transforming it into value-added materials.

Keywords*:* Cotton waste, Fabric properties testing, Needle felting, Wool waste, Cotton-wool blends

1. Introduction

The global textile industry has generated over 92 million tons of waste, and less than 15% has been recycled. Moreover, Asia has contributed nearly 60% of this total [1]. The textile waste is mainly divided into pre-consumer and post-consumer waste. Pre-consumer textile waste is generated during manufacturing, comprising materials that were not incorporated into the final consumer product. In contrast, post-consumer textile waste is generated following the utilization of garments and household textiles, such as clothing and textile products at the end of their life cycle [2]. However, compared to the post-consumer fabric wastes, pre-consumer fabric wastes are better suited for re-use. Studies have shown that the environmental impact of post-consumer waste is on the rise, and this rise is mainly due to a lack of proper recycling facilities [3], which often contain contaminants and unknown materials [4]. Conversely, pre-consumer waste offers a more homogenous and clean input for recycling, positioning it as perfect for circular interventions and local re-use strategies, especially within urban fashion networks [5]. Cotton wastes have been recycled via mechanical and chemical processes and have been used as raw materials for other applications. Research has estimated that over 100 million metric tons of cotton waste are being generated globally each year, representing approximately 35–40% of the total textile waste produced worldwide. Despite the significant scale of this issue, less than 30% of this cotton waste is currently being recycled, and a lot of the shorter cotton fibers (under 7 millimeters) are being thrown away during processing and remain under-utilized [6]. In a focused study, research by Johnson et al. [7] found that approximately 11.6 million metric tons of cotton waste are generated annually from cotton garment production alone, which underscores the significant scale of pre-consumer textile waste. In addition, cotton waste, which has undergone processing and

development, can be efficiently employed as the new raw materials that can be utilized to create a wide range of products, including new fibers, fabrics, and textiles.

Wool, a natural and biodegradable protein fiber, poses unique recycling difficulties and prospects due to its chemical composition and treatment. Researchers have examined various valorization strategies for raw wool waste, such as its use in composting and in producing insulation materials, as well as reconstituting it into regenerated fibers through both chemical and mechanical means [8, 9]. Industrial-scale initiatives, like the production of wool fibers, demonstrate the feasibility of creating high-quality recycled wool that is suitable for fashion applications, while also lowering its environmental impact [10]. A Life Cycle Assessment (LCA) study conducted by Wiedemann et al [11] revealed that closed-loop recycling can markedly reduce carbon footprints when compared to the processing of virgin wool.

Textile recycling technologies have made great headway in cutting back on waste and environmental problems. Mechanical and chemical recycling methods allow valuable fibers to be recovered from industrial waste. Hence, resources are saved that would otherwise be lost to landfills. The mechanical recycling of these wastes, which involves the shredding and re-spinning of the fibers, is the most widely adopted technique because it requires no harmful solvents and uses less energy and water than virgin fiber production. Chemical recycling breaks the fibers back into their original chemical components, which can then be rebuilt into new fiber, supporting a closed-loop production system. These methods help to reduce greenhouse-gas emissions and minimize dependence on new raw materials. As a result, circular-economy strategies and efficiency are supported within the fashion sector [12-14]. Mechanical recycling that is based on the shredding and re-spinning of fibers often leads to fiber breakage and reductions in fiber quality [13]. Chemical recycling can recover fiber that is close to virgin quality. However, it still remains costly and is energy-intensive, which is largely due to the requirement for clean and uniform input materials [15]. Recycling blended fabrics including cotton-polyester and cotton-elastane is highly demanding because the process of separating the components demands additional chemical or thermal treatments that may generate harmful emissions or impair the properties of the fibers [16]. In this world, less than 15% of textiles are recycled, which means that most of the waste is still being burned or sent to landfills [1].

Needle felting is a dry textile technique that utilizes barbed needles to mechanically interlock fibers into a dense non-woven fabric. The needles repeatedly punch through the fibrous textile substrate, grabbing the fibers and pulling them all together over and over again. Thereby, the fabric is formed without the need for water, heat, or adhesives. This technique provides an environmentally sustainable and resource-efficient approach to textile production. Needle felting has been widely used to create decorative and functional items, such as garments and accessories. This technique enables the creation of one-of-a-kind non-woven fabrics with unique textures and special designs, which offer benefits that are both functional and visually appealing. In the Pandemonium project, the designer utilized needle felting as a primary technique to transform pre-consumer and post-consumer textile wastes into new unique wearable textiles. In particular, the designer shredded garments in eight distinct colors using an industrial shredder, and then randomly distributed the textile scraps onto a base layer of black deadstock cotton twill fabric. This layered material was then processed using needle felting, which mechanically intertwined the fibers by passing needles through the fabric 40 times, thereby creating a novel non-woven felted textile.[17] Regarding the function of this innovative needle-felted textile, the study showed that the cotton wastes had been used to generate a non-woven mat, which could be used as a soil mulch. Moreover, it was thicker than synthetic mulch and contributed to better heat retention and temperature control of the soil. The mat also demonstrated a great ability to suppress weeds, turning it into a sustainable agricultural solution that could be made from needle-felted cotton waste textiles.[18] Choudhury et al.[19] highlighted the fact that needle-punched non-woven textiles made from natural or waste fiber offer a sustainable route for circular textile production. The process minimizes water and chemical use while transforming mixed fiber waste into functional, biodegradable materials. The adaptability allowed applications in insulation, automotive interiors, and composites, which proved its industrial relevance. Because it relies on mechanical entanglement rather than chemical bonding, needle-felting efficiently integrates different fiber types. Consequently, both environmental impact and production costs are reduced, making it a promising low-resource technology that can be employed to convert heterogeneous textile waste. Thus, through needle felting, cotton waste has been able to be effectively incorporated into new value-added textiles and products, which demonstrates the potential for this technique to transform textile waste into innovative, functional, and environmentally friendly materials [20].

Evaluating a textile's physical properties is important in order to determine its quality, functionality, and suitability for use. Since textiles are being used in diverse industries, it is becoming increasingly important to systematically assess their physical characteristics. Physical property testing allows manufacturers and researchers to evaluate key factors, such as tensile strength, abrasion resistance, moisture management, and thermal behavior. [21] In one study, the researcher made different types of fabrics using old cotton, such as non-woven, woven, quilted, and tufted fabrics. The results showed that cotton textiles are able to maintain satisfactory physical performance, permitting them to be re-purposed and utilized in the creation and manufacture of new products, such as bags, jackets, and home accessories [22]. In other similar research conducted using needle-felted wool and silk waste fabric, the fabric property testing clearly showed that textile waste materials, such as wastes

consisting of silk and wool fibers had exhibited beneficial functional properties. Non-woven fabrics with higher wool waste content were found to be thicker, stronger, more breathable, and better at retaining warmth, while silk waste-based fabrics were determined to be lighter and softer. The findings indicated that both fiber waste types had been able to retain their valuable functional characteristics, enabling them to be re-purposed and integrated into the production of high-quality materials that are suitable for use as thermal interlinings [23]. Thus, textile property testing, which provides critical information, allows researchers and manufacturers to identify innovative methods that can be used to re-purpose textile wastes into functional and sustainable materials. Given that in the past there was limited data on blended cotton–wool waste fabrics, previous research studies mostly explored decorative or single-fiber needle-felting. Therefore, this study aimed at the following: (i) testing the strength and structure of cotton–wool waste blends created by using needle-felting, (ii) finding the best blend ratios for strength and abrasion resistance, and (iii) showing a sustainable way to re-use textile waste.

2. Materials and methods

2.1. The cotton waste

The cotton waste used in this study was sourced from Golden Kerin Co., Ltd., a factory located in Samut Prakan Province in the Metropolitan Bangkok Region. The company has been operating for over 30 years and specializes in the production of cotton towels and nappies. It operates 15 weaving machines that are used to manufacture cotton nappy fabrics. Pre-consumer cotton waste is generated daily during the fabric edge trimming process in weaving, which amounts to approximately 10 kilograms per day. Moreover, the cotton waste is sold to recycling companies for approximately 10 baht per kg so that it can be transformed into new cotton fibers. Furthermore, the factory owner has proposed that the cotton waste generated from towel and nappy fabric production could be re-purposed into new textile materials and products. These cotton yarn offcuts have been collected and used in fiber blending experiments. As shown in Figure 1 below, the cotton waste resembles yarn in appearance.

2.2 The wool waste

The wool waste utilized in this study was obtained from the Pang Tong Wool Weaving Group, which is located in Mae Hong Son Province in Thailand. This local community group has engaged in traditional wool production and textile weaving. The group presently maintains two primary breeds of sheep for their wool harvesting: Bond and Corriedale. These breeds were selected for their fiber quality and their ability to adapt to the regional climate. During each wool collection cycle, approximately 1,200 kilograms of raw wool are harvested. Of this total, approximately one-third is classified as waste due to contamination, poor fiber quality, or damage that was incurred during shearing and the initial processing. As shown in Figure 2, the wool waste is usually disposed of by burning because the locals do not know how to manage or re-used them to create new materials.

2.3 Preparing materials and Carding

The cotton waste was first collected and then manually cut into small pieces (approximately less than 1 cm). This was accomplished by placing the cotton waste into used paper, rolling it tightly, and then cutting it into smaller pieces. Figure 3 shows that during the cutting stage, the paper was cut along with the cotton waste to maintain the smaller shape and the structural integrity of each piece to allow for easier carding. The first step in preparing the wool waste was a cleaning process called carbonising, which removes grease and plant materials, such as seeds, grass, and burs from the wool. To begin, the wool waste was soaked in a sulphuric acid (H_2SO_4) solution at a ratio of 1:50 (1 liter of sulphuric acid per 50 liters of water), which breaks down the plant material into carbon. Then, the wool was dried in an oven at 95°C to 120°C, making the remaining plant material brittle [24]. After that, the wool waste was manually opened by hand to minimize fiber clumping and to enhance initial fiber separation before the carding process.



Figure 1 The cotton waste yarn



Figure 2 The wool waste



Figure 3 The process of preparing the wasted cotton yarns

2.4 The carding process

In this study, the blended fiber webs were prepared using cotton and wool waste in three specific weight ratios: 80% Cotton / 20% Wool (80C/20W), 50% Cotton / 50% Wool (50C/50W), and 20% Cotton / 80% Wool (20C/80W). Before carding, each fiber type was weighed separately according to the target blending ratios. Additionally, the wool fibers were dyed in dark colors to assess how well the cotton waste would visually blend with the dyed wool at the different proportions of blending. After carding, high-resolution digital imaging with a zoom camera was used to examine the fiber surfaces and to evaluate the degree of fiber mixing and distribution. Each blend was assigned a sample label, the 80C/20W blend was designated as Sample A, the 50C/50W blend as Sample B**,** and the 20C/80W blend as Sample C**.**

The Mesdan Lab carding machine (Code 337A) was used in the experiment, the machine was equipped with a wide conveyor belt, two feeding rollers, three pairs of stripper and worker cylinders. The fibers were gently pre-mixed and fed into the carding machine in alternating handfuls in order to promote better distribution. To ensure the uniformity of fiber alignment and blending, each fiber blend was carded twice**.** This repeated carding step was

critical as explained in the *Handbook of Non-wovens* [25]. During carding, when the fibers are more intensively processed to separate them into individual strands and to form a uniform web, there is a higher risk of fiber damage, nep formation, and poor-quality fabric. For this reason, carding the fiber twice helps to reduce fiber damage, improve fiber alignment, and produce a more consistent and well-blended web. A gradual, repeated carding approach enhances web quality by minimizing defects like neps and ensures better mixing of the tearing strengths of the different fiber types. During the first pass through the carding machine, the fibers were loosened, separated, and roughly aligned, helping to initiate the blending process. The second carding pass further improved the uniformity of the web by enhancing the fiber alignment and ensuring a more thorough integration of the cotton and wool components. The resulting output was a consistent and evenly mixed fiber web or sliver that is suitable for subsequent textile manufacturing stages.

2.5 Needle felting

The needle felting machine used in this study was the Janome FM725 model, which is equipped with five barbed needle units and operates at a capacity of 900 needle punches per minute. A non-woven cotton sheet was also used as a batting layer during the felting process with the blended fibers. In order to calculate the blended fibers at 4 grams per 10 × 10 cm, grids were drawn all over non-woven cotton squares (10 × 10 cm). After completing the felting process, each blended fiber sample was labeled for identification. The sample containing 80% cotton and 20% wool was designated as Sample A1, the 50% cotton and 50% wool was labeled as Sample B2, and the sample composed of 20% cotton and 80% wool was referred to as Sample C3. These sample labels were consistently applied throughout the study to clearly distinguish among the different cotton-wool fiber blend ratios during all stages of testing and analysis.

2.6 Testing the properties of the fabrics

Following the needle felting process, the structural and mechanical properties of the resulting felted fabric samples were assessed using standardized textile testing. The thickness of the felted fabric was measured using a portable gauge to determine the dimensional properties of the material. This evaluation aimed at analyzing the bulk and surface uniformity of the fabric. Breaking strength and elongation were tested with the BS EN ISO 9073-18:2008 Test methods for non-wovens-Part 18 in order to determine the breaking strength and elongation of the non-woven materials using the grab tensile to conduct the grab tensile test. This method is used to determine the tensile performance of non-woven fabrics under unidirectional stress. In this test, a part of the fabric is held tightly in place while tensile force is applied. The data consisted of the maximum force that the fabric could withstand before breaking and the percentage of elongation. These measurements showed how the fabric resists stretching and force, which are key measures of a fabric's durability and practical performance. Tear resistance was evaluated following the BS EN ISO 9073-4:1997 Test methods for non-wovens-Part 4 in order to determine the tear resistance so that a fabric's ability to resist the propagation of an existing tear under applied tension could be assessed. For fabrics designed for industrial or practical use, tear resistance is essential due to the possibility of accidental snags or mechanical stress. This test helps to determine how strong and reliable a non-woven material is under such conditions. Abrasion resistance was tested according to ISO 12947-3:1998 Textiles — Determination of the abrasion resistance of fabrics using the Martindale Method Part 3, which defines the procedure for determining mass loss that is the result of surface wear. In order to ascertain mass loss, fabric samples were rubbed against a standard abrasive surface using specific pressure and motion settings. The weight of each sample was measured before and after testing to determine how much material had been lost as a result of the abrasion. The test measures how well the fabric can handle repeated rubbing, effectively simulating wear under real-world conditions. Strong abrasion resistance is important for items like jackets, furniture fabrics, and specialized textiles, for which durability impacts both function and longevity. During all testing, five replications were conducted for each specimen to ensure the accuracy and reliability of the data.

3. Results and discussion

3.1 Carding result from the digital zoom camera

The carded web of Sample A (80% Cotton/20% Wool) was composed of cotton waste fibers with a minimal amount of black-dyed wool waste fibers. The cotton fibers mostly appeared over the surface, while the crimped wool fibers existed throughout the structure. The inclusion of wool likely enhanced fiber cohesion and interlocking, contributing to structural stability during the subsequent non-woven processing. Sample B (50% Cotton/50% Wool) showed a balanced division of cotton and wool waste fibers, with the black-dyed wool fibers openly visible and well-integrated throughout the structure. With both fibers present in equal amounts, the crimped nature of the wool fibers introduced loft and volume, contributing to a more cohesive and textured

surface. Sample C (20% Cotton/80% Wool) revealed a compact and uniform distribution of crimped, dark wool fibers, clearly reflecting the dominance of the wool within the carded web. The few visible white cotton waste fibers, which were barely distinguishable, contributed primarily to the surface contrast. The pronounced crimp and bulk of the wool waste contributed to increased loft and fiber entanglement, supporting better cohesion within the structure.

(A) (B) (C)



Figure 4 Sample A (Cotton 80%/Wool 20%), Sample B (Cotton 50%/Wool 50%), and Sample C (Cotton 20% /Wool 80%)

3.2 Thickness and texture

The thickness measurements of the cotton/wool needle-punched non-woven fabrics revealed a clear pattern fabric thickness, which was found to increase with higher wool content. The 80C/20W (A1) sample exhibited the lowest average thickness at 0.982 mm, while the 50C/50W (B2) and 20C/80W (C3) samples measured 1.228 mm and 1.414 mm, respectively. This progression can be attributed to wool's crimped and elastic morphology, which increases both the bulk and a resistance to compression within the web [26]. Conversely, higher intensities of needling can counteract this effect by compacting the web structure. Similarly, Omrani et al. [27] reported that increasing the needle density had enhanced fiber interlocking and packing within flax non-woven fabrics, resulting in higher tensile strength and improved structural uniformity. However, they also noted that excessive needling can lead to excessive compaction, which decreases the thickness and porosity of the fabric, indicating the need to balance the bonding density in order to maintain both strength and bulk.

(A1) (B2) (C3)



Figure 5 Sample A1 (Cotton 80%/Wool 20%), Sample B2 (Cotton 50%/Wool 50%), and Sample C3 (Cotton 20% /Wool 80%)

3.3 Properties testing

As shown in Table 1, the blend composition of the cotton and wool had a marked influence on the fabric mass retention after the needle-felting process. The 80C/20W blend exhibited the lowest average mass loss (0.0205 g), while the 20C/80W blend showed the highest (0.077 g). This indicated that increasing wool content had increased fiber loss during abrasion. The greater mass loss of the wool-rich samples can be explained by the fiber's scaly cuticle structure, which is composed of overlapping keratin cells that create higher surface friction and promote fiber-to-fiber entanglement. Under repeated rubbing, these scales interlock and form surface pills that eventually detach, contributing to material loss. Barella et al.[28] noted that blending with smoother fibers, such as cotton, mitigates frictional shear by reducing inter-fiber locking. The comparatively low mass loss of the 80C/20W

sample supported this, suggesting that cotton's smoother morphology helps to more evenly dissipate mechanical stress. This dual behavior underscores a fundamental limitation of wool-rich non-woven fabrics: improved structural loft comes at the cost of reduced surface durability**.** Consequently, optimizing both needle density and surface finishing becomes essential in order to counteract the abrasion vulnerability inherent in high-wool blends. The five replication measurements for mass loss were as follows: the 80C/20W (A1) sample recorded 0.0190, 0.0200, 0.0205, 0.0210, and 0.0220 g; the 50C/50W (B2) sample recorded 0.0340, 0.0350, 0.0360, 0.0370, and 0.0393 g; and the 20C/80W (C3) sample recorded 0.0720, 0.0750, 0.0770, 0.0790, and 0.0820 g.

Table 1 Mass loss testing

Average Before (g)	Average After (g)	Average Loss of Mass (g)
0.34425	0.32375	0.0205
0.39025	0.35400	0.03625
0.42675	0.34975	0.07700

Table 2 Tensile, Elongation, and Tearing

Cotton/Wool	Tensile (N)	Elongation (%)	Tearing (N)
80C/20W(A1)	14.2	42.03	8.42
50C/50W(B2)	15.15	51.48	10.54
20C/80W(C3)	17.46	58.07	14.69

As shown in Table 2, the experimental results revealed a clear correlation between the proportion of wool in cotton/wool blends. The blend with 20% Cotton and 80% Wool (C3) exhibited the highest tensile strength at 17.46 N and the greatest elongation at 58.07%**.** As the cotton content was increased, both properties declined. The 50C/50W (B2) blend showed a tensile strength of 15.15 N and elongation of 51.48%**,** reflecting a moderate reduction in performance. The 80C/20W(A1) had the lowest tensile strength at 14.20 N and the lowest elongation at 42.03%.

The results demonstrated that increasing the wool content had enhanced the ability of the fabric to both withstand tensile force and to stretch before breaking. This is consistent with findings from textile science, which revealed that wool's crimped and elastic fiber structure contributes to improved strength and extensibility in composite and non-woven materials. According to Patrucco et al. [29], the internal protein links in wool (α-keratin and hydrogen bonds) give it strong resilience and flexibility compared to other natural fibers. Therefore, the greater tensile performance in wool-rich blends reflects both the elastic nature of wool and its ability to form strong connections in the fabric, whereas cotton's more rigid, inelastic nature limits both strength and extensibility.[30] The five replication measurements for tensile strength were as follows: A1 recorded 13.8, 14.0, 14.2, 14.4, and 14.6 N; B2 recorded 14.7, 15.0, 15.2, 15.3, and 15.55 N; and C3 recorded 16.8, 17.2, 17.5, 17.7, and 18.1 N. For elongation, the five replications for A1 were 40.8, 41.6, 42.0, 42.7, and 43.05%; for B2, 49.8, 50.9, 51.4, 52.2, and 53.1%; and for C3, 56.0, 57.3, 58.1, 59.0, and 59.95%. The results of tearing from Table 2 show that the observed increase in tearing strength with higher wool content in the cotton and wool needle-punched non-woven blends was strongly supported by the existing textile literature. According to Russell [25], wool fibers possess inherent crimp and elasticity that promote intensive fiber entanglement during the needle felting process, thereby creating a denser and more energy-absorbing structure. This interlocking network enables wool-rich fabrics to better resist tear propagation by distributing stress across multiple bonding points. The present results confirmed that fiber bonding had increased with higher wool content given that the flexible and spring-like wool fibers had re-aligned and compacted under needling. Consequently, the tearing strength rose from 8.42 N in the 80C/20W blend to 14.69 N in the 20C/80W blend. However, while this structural densification improves resistance to tearing, it suggests that with excessive wool content, flexibility could be traded for strength. These findings highlight the need to balance fiber composition in order to optimize both durability and comfort in non-woven composites. The five replication measurements for tearing strength were: A1 recorded 8.10, 8.25, 8.40, 8.55, and 8.80 N; B2 recorded 10.10, 10.35, 10.55, 10.75, and 10.95 N; and C3 recorded 14.10, 14.45, 14.70, 14.95, and 15.25 N.

4. Conclusions

The findings demonstrated that fiber blend ratios play a decisive role in defining the structural and mechanical behavior of cotton–wool needle-felted fabrics. Increasing the wool content had enhanced fabric thickness, tensile strength, elongation, and tear resistance, all of which confirmed wool's contribution to elasticity and structural

cohesion through its crimped morphology. In contrast, higher cotton content had improved surface stability and abrasion resistance, indicating its value in controlling fiber shedding and dimensional uniformity. These results revealed a complementary relationship between the two fibers, suggesting that an optimized blend can balance strength, smoothness, and durability. Beyond performance, the study's results underscored the broader value of this sustainable approach. Not only does transforming pre-consumer cotton and wool waste into non-woven fabrics divert materials from landfills or incineration, but it also reduces production costs and supports community circular economy initiatives. By linking local wool resources with industrial cotton waste, this method offers a practical and scalable pathway toward low-impact textile manufacturing. The results also aligned with previous studies, which reported that fiber crimp and blend composition critically affect the integrity of non-woven fabrics, reinforcing the potential of utilizing mixed natural-fiber waste systems to develop durable, eco-efficient materials.

This research had some limitations. Firstly, the fabric samples were made and tested in a small lab setting, so the results might not fully reflect what could happen in large-scale production. Making these fabrics on an industrial scale could lead to different outcomes. Secondly, since the materials used were cotton waste and wool waste, the quality of the materials wasn't always consistent because the fibers were of different lengths and had some damage. In addition, leftover dirt or other materials could have been present. Any of these factors could have affected the blending and final quality of the fabric. Although every effort was made to uniformly prepare and blend the fibers, slight differences in the waste fibers may have affected the results. Thirdly, another limitation is that the study only tested a few basic properties: thickness, abrasion resistance, tensile strength, tear strength, and elongation. These are important, but other properties, such as drape, flexibility, thermal insulation, air permeability, moisture management, and flame resistance, were not evaluated. To fully understand how these fabrics will behave when used in the real world, more testing will be needed. All the felting was done using a small machine, and the process was adjusted just for lab work. If this method were to be used in a factory, there might be new challenges, such as keeping the fabric weight even, properly mixing large amounts of fibers, or running machines at high speed. All of these issues were beyond the focus of this study.

5. Acknowledgements

The authors would like to thank the Golden Kerin Co., Ltd., which provided the cotton waste, as well as the Pang Tong Wool Weaving Group from whom the wool waste was obtained.

6. Author Contributions

Visesphan, K.: Conceptualization, Methodology, Writing (original draft), Software, Investigation, Formal analysis, Data curation, Writing – review & editing, Resources, and Funding acquisition; Vongphantuset, J.: Visualization, Supervision; and Writing – review & editing; and Joenurairatana, E.: Project administration

7. Conflicts of interest

The authors declare that there were no conflicts of interest.

8. References

[1] Niinimäki K, Peters G, Dahlbo H, Perry P, Rissanen T, Gwilt A. The environmental price of fast fashion. Nat Rev Earth Environ. 2020;1(4):189-200.

[2] Rasu MNS, Kwon WS, Chattaraman V. From waste to wear: Perceived risks associated with recycled post-consumer textile waste (PCTW) denim products. Int Textile Apparel Assoc Annu Conf Proc. 2025;81(1).

[3] Durrani H, Clarke-Sather AR, Alves PH. Prospective life cycle assessment of nonwoven mat manufacturing: Comparing pre-consumer wood waste fibers to post-consumer recycled apparel fibers. Proc Int Des Eng Tech Conf Comput Inf Eng Conf. 2024;5:V005T05A020.

[4] Kahoush M, Kadi N. Towards sustainable textile sector: Fractionation and separation of cotton/polyester fibers from blended textile waste. Sustain Mater Technol. 2022;34:e00513.

[5] Ferrero-Regis T, Lindquist M, van Lunn C, Hopper C. Mapping fashion networks and pre-consumer textile flows for circular communities. Int J Sustain Fashion Textiles. 2024;3(2):155-178.

[6] Wang C, Su J, Liu T, Ge S, Liew RK, Zhang H, et al. A sustainable strategy to transform cotton waste into renewable cellulose fiber self-reinforcing composite paper. J Clean Prod. 2023;429:139567.

[7] Johnson S, Echeverria D, Venditti R, Jameel H, Yao Y. Supply chain of waste cotton recycling and reuse: A review. AATCC J Res. 2020;7(S1):19-31.

[8] Maier SS, Rajabinejad H, Buciscanu II. Current approaches for raw wool waste management and unconventional valorization: A review. Environ Eng Manag J. 2019;18(7):1439-1456.

[9] Lebedytė M, Sun D. A review: Can waste wool keratin be regenerated as a novel textile fibre via the reduction method? J Text Inst. 2022;113(8):1750-1766.
[10] Bianco I, Gerboni R, Picerno G, Blengini GA. Life cycle assessment (LCA) of MWool® recycled wool fibers. Resources. 2022;11(5):41.
[11] Wiedemann SG, Biggs L, Clarke SJ, Russell SJ. Reducing the environmental impacts of garments through industrially scalable closed-loop recycling: Life cycle assessment of a recycled wool blend sweater. Sustainability. 2022;14(3):1081.
[12] Sandin G, Peters GM. Environmental impact of textile reuse and recycling–A review. J Clean Prod. 2018;184:353-365.
[13] Kim EH, Lee H. Comprehensive review of textile waste recycling: From origins to innovations. Fibers Polym. 2025;26:1449-1464.
[14] Lee J, Park CH, Yun C, Lee S. Textile waste management and its sustainability: a review. J Mater Cycles Waste Manag. 2025;27:2183-2197.
[15] Seifali Abbas-Abadi M, Tomme B, Goshayeshi B, Mynko O, Wang Y, Roy S, et al. Advancing textile waste recycling: Challenges and opportunities across polymer and non-polymer fiber types. Polymers. 2025;17(5):628.
[16] Choudhury K, Tsianou M, Alexandridis P. Recycling of blended fabrics for a circular economy of textiles: Separation of cotton, polyester, and elastane fibers. Sustainability. 2024;16(14):6206.
[17] Yatvitskiy M, Roelse K, Cobb K, Cao H, Gorea A. Pandemonium. Int Textile Apparel Assoc Annu Conf Proc. 2022;79(1).
[18] Cao H, Ludwig K, Cobb K, Scott C, Jin Y, Knight B, et al. Development and research of sustainable mulch mats from end-of-use cotton textiles. Int Textile Apparel Assoc Annu Conf Proc. 2024;80(1).
[19] Choudhury K, Tsianou M, Alexandridis P. Recycling of blended fabrics for a circular economy of textiles: Separation of cotton, polyester, and elastane fibers. Sustainability. 2024;16(14):6206.
[20] Sharma R, Goel A. Development of nonwoven fabric from recycled fibers. J Textile Sci Eng. 2017;7:289-292.
[21] Günaydın GK, Çeven EK. A research on tensile and abrasion properties of fabrics produced from conventional and fire resistant type polyester yarns. Ind Textila. 2017;68(6):407-414.
[22] Cao H, Cobb K, Yatvitskiy M, Wolfe M, Shen H. Textile and product development from end-of-use cotton apparel: A study to reclaim value from waste. Sustainability. 2022;14(14):8553.
[23] Govindaraju R. Certain properties of needle punched nonwoven fabrics made from silk and wool fibers. Trends Text Eng Fash Technol. 2018;1(2).
[24] The Woolmark Company. Scouring and carbonising [Internet]. Sydney: The Woolmark Company; [cited 2025 Jul 27]. Available from: https://www.woolmark.com/industry/product-development/wool-processing/woollen-scouring-carbonising/
[25] Russell SJ, editor. Handbook of nonwovens. 2nd ed. Cambridge: Woodhead Publishing; 2022.
[26] Singha K, Singha M. Fiber crimp distribution in nonwoven structure. Front Sci. 2013;3(1):4-21.
[27] Omrani F, Soulat D, Ferreira M, Wang P. Effects of needle punching process and structural parameters on mechanical behavior of flax nonwovens preforms. Adv Aircr Spacecr Sci. 2019;6(2):157-168.
[28] Manich AM, de Castellar MD, Saurí RM, Miguel RAL, Barella A. Abrasion kinetics of wool and blended fabrics. Text Res J. 2001;71(6):469-474.
[29] Patrucco A, Zoccola M, Anceschi A. Exploring the potential applications of wool fibers in composite materials: A review. Polymers. 2024;16(16):2360.
[30] Bunsell AR, editor. Handbook of properties of textile and technical fibres. 2nd ed. Duxford: Woodhead Publishing; 2018.