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# Blending of Natural (Stinging Nettle) and Synthetic Fiber (Nylon 6,6): Enhancing Performance and Sustainability

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**Abstract**
The textile and composite industries are constantly evolving to develop materials that balance performance, durability, and environmental sustainability. Stinging nettle (Urtica dioica) is a promising natural fiber due to its high tensile strength and eco-friendliness, while Nylon 6,6 is a durable synthetic fiber known for its resilience and mechanical properties. This study investigates the blending of stinging nettle fibers with Nylon 6,6 to enhance fabric performance while promoting sustainability. This study explores the potential of blending stinging nettle fibers with Nylon 6,6 to develop a hybrid textile material that integrates the strengths of both fiber types. The research focuses on evaluating the mechanical properties (tensile strength, elongation, and abrasion resistance), comfort (moisture management, thermal regulation), durability, and environmental impact of the composite fabric.

**Keywords:** Natural fibers, synthetic fibers, fiber blending, textile sustainability, mechanical properties, environmental impact

## 1. Introduction

Textile materials are a part of daily life, and they have various applications in different industries such as fashion, automotive, medical, aerospace, and technical textiles. The ongoing development of textile engineering has resulted in the creation of fabrics that meet performance, comfort, durability, and sustainability requirements. Textile fibers are generally classified as natural and synthetic fibers, each having its own advantages and limitations. Natural fibers made from cotton, wool, flax, and hemp are prized for their ease of biodegradation, breathability, and softness but frequently fall short in terms of the mechanical resilience, elasticity, and endurance for sustained application within high-performance regimes. Synthetic products based on polyester, nylon, and acrylic fibers were engineered in an attempt to eliminate these inadequacies while providing high levels of tensile strength, suppleness, and protection against degradation from environmental components. While their benefits, they play a large role in plastic waste and carbon footprints, making their long-term environmental consequences uncertain.

Fiber blending, or mixing natural and synthetic fibers, has proven to be an effective means of maximizing textile characteristics. Fiber blending allows for the creation of hybrid materials that balance the mechanical properties of synthetic fibers with the environmental and comfort factors of natural fibers. Among the numerous natural fibers, stinging nettle (Urtica dioica) has drawn interest due to its high tensile strength, moisture-wicking properties, and environmentally friendly cultivation process. Stinging nettle is unlike conventional natural fibers because it can be cultivated using low water, pesticides, and fertilizers,

rendering it an eco-friendly substitute.
Conversely, Nylon 6,6, a commonly used synthetic fiber, is known for its outstanding resilience, high elasticity, abrasion resistance, and chemical stability. It is widely used in sportswear, industrial fabrics, and technical uses because it is strong and performs well. Through the incorporation of stinging nettle fibers with Nylon 6,6, this research seeks to investigate the creation of a new hybrid textile that synergizes the strength, comfort, and sustainability of stinging nettle with the durability and mechanical strength of Nylon 6,6.

## 2. Literature Review

Many studies have investigated fiber blending as a suitable approach for upgrading fabric properties using the advantage of natural and synthetic fibers. Different types of fibers are mixed by researchers in a bid to improve mechanical strength, elasticity, durability, moisture transport, and the environmental profile.
A study by Smith et al. (2020) points out that the combination of cotton with polyester produces fabrics with higher tensile strength and wrinkle resistance without compromising on breathability. Cotton, being a natural fiber, is soft and absorbs moisture but wrinkles easily and is not durable. The addition of polyester, an artificial fiber known for great resilience and form memory, balances these shortcomings and creates a material which is both more durable and wear- and deformation-resistant.
Likewise, Gupta & Rao (2019) researched natural-synthetic fiber composites and determined that they have better mechanical properties than those of pure natural fiber materials. Their work highlighted those natural fibers, though environmentally friendly, tend to have poor elongation and decreased durability under stress. Adding synthetic fibers to the mix increases the overall elasticity, toughness, and lifespan of the fabric, which is ideal for uses with high-performance fabrics like sportswear, automobile interiors, and industrial textiles.

### 2.1 Sustainability and Eco-Friendly Innovations

With the growing environmental concerns, scientists have also investigated the use of fiber blending as a way to lower the ecological impact of textile manufacturing. Chen et al. (2021) examined sustainable innovations like the use of recycled polyester in fiber blending. According to their research, the use of recycled synthetic fibers greatly reduces the carbon footprint and plastic waste generated by conventional textile production. Moreover, the combination of recycled polyester with natural fibers such as organic cotton or hemp ensures that fabric performance is preserved while minimizing the use of virgin synthetic fibers. This transition to sustainable fiber composites is in line with international efforts to encourage circular economy practices in the textile sector.

### 2.2 Relevance to Stinging Nettle and Nylon 6,6 Blending

The results of these studies form a solid basis for investigating stinging nettle-Nylon 6,6 fiber blends. Where cotton-polyester blends maximize strength and comfort, a stinging nettle-Nylon 6,6 blend can potentially maximize durability, elasticity, and breathability with a more sustainable substitute for fully synthetic fabrics. Increasing research on blending fibers highlights the necessity for future innovations that find a balance between performance and sustainability, leading the way to the creation of sustainable, high-performance textiles.

## 3. Methodology

### 3.1 Selection of Materials

The selection of materials for this study was based on their mechanical performance, sustainability, and suitability for fiber blending. This research focuses on stinging nettle (Urtica dioica) as the natural fiber and Nylon 6,6 as the synthetic fiber, both chosen for their unique properties and potential for hybrid textile development.

**3.1.1. Natural Fiber: Stinging Nettle (Urtica dioica)**

Stinging nettle has gained attention as a sustainable and high-performance natural fiber due to its exceptional strength, breathability, and eco-friendly cultivation. Comparable to flax and hemp, stinging nettle fibers exhibit excellent durability, making them suitable for textile applications. The fiber has good moisture-wicking capabilities, enhancing comfort and thermal regulation. Unlike conventional crops such as cotton, stinging nettle requires minimal water, pesticides, and fertilizers, reducing its environmental impact. Its porous structure allows for better air circulation, making it ideal for comfortable fabrics. As a natural fiber, stinging nettle decomposes naturally, addressing concerns related to textile waste and microplastic pollution.

**3.1.2. Synthetic Fiber: Nylon 6,6**

Nylon 6,6 is a widely used synthetic fiber known for its strength, elasticity, and abrasion resistance. Provides high tensile strength and elasticity, making it ideal for durable fabrics. Unlike natural fibers, Nylon 6,6 exhibits excellent resistance to friction, prolonging fabric lifespan. Enhances the fabric's ability to retain its form and resist wrinkling, improving longevity. Offers protection against moisture, mildew, and chemicals, increasing durability in various environmental conditions. Nylon 6,6 effectively enhances the properties of natural fibers, improving fabric resilience without significantly compromising comfort.

## 4. Justification for Blending Stinging Nettle and Nylon 6,6

The combination of stinging nettle and Nylon 6,6 aims to develop a textile material that integrates natural sustainability with synthetic durability. Nylon 6,6 reinforces the mechanical properties of stinging nettle, making the fabric more robust. Stinging nettle fibers improve breathability and moisture absorption, compensating for the lack of natural comfort in synthetic fabrics. Reducing the dependency on synthetic fibers helps minimize environmental pollution while maintaining performance. The hybrid fabric can be utilized in apparel, upholstery, sportswear, and technical textiles, offering a versatile and eco-friendly alternative to traditional materials.

This research aims to evaluate the mechanical, thermal, and environmental properties of the stinging nettle-Nylon 6,6 blend, providing insights into its suitability for sustainable textile innovations.

## 4. Experimental Procedure

### 4.1 Blending Process:

To evaluate the impact of fiber composition on textile performance, stinging nettle (Urtica dioica) and Nylon 6,6 fibers were blended in different ratios. The blending process was designed to optimize mechanical strength, elasticity, moisture management, and environmental sustainability while ensuring fabric durability.

Blending Ratios: The fibers were blended in two primary compositions to assess performance variations:

- 70:30 (Nylon 6,6: Stinging Nettle) – A natural fiber-dominant blend aimed at maximizing sustainability and breathability while incorporating Nylon 6,6 for durability and elasticity.
- 50:50 (Stinging Nettle: Nylon 6,6) – An equal ratio blend designed to balance the advantages of both fibers, offering an optimal combination of strength, flexibility, and comfort.

**4.2 Mechanical Blending:**

Fibers were carded and combed to achieve even distribution and prevent fiber clumping. A controlled blending process ensured proper alignment of fibers, enhancing the structural integrity of the final yarn.

**4.3 Spinning Process:**

The spinning process plays a crucial role in determining the **structural integrity, fineness, and mechanical properties** of yarns. For this study, the blended fibers of **stinging nettle and Nylon 6,6** were spun using the **ring spinning technique**, which is widely used in the textile industry for producing **high-strength, fine, and uniform yarns**. Ring spinning is a versatile and efficient method for producing high-quality yarns with superior tensile strength, smoothness, and elasticity. Blending natural and synthetic fibers requires modifications in the ring spinning process to optimize fiber cohesion and minimize breakage. Pre-blending fibers before carding to ensure even distribution. Adjusting spinning speed and twist per inch (TPI) to balance strength and flexibility. Optimizing draft ratios to accommodate the different fiber lengths and stiffness of stinging nettle and Nylon 6,6.

Fiber preparation
(Cleaning, opening, and carding the fibers to form a uniform sliver.)

↓

Drawing
(The sliver is elongated to align and straighten fibers for better consistency.)

↓

Roving
(A slight twist is added to create a fine strand with increased cohesion.)

↓

Spinning
(The roving is further drawn, twisted, and wound onto a bobbin, forming the final yarn.)

**4.4 Fabric Formation:**

Blended yarns offer a unique combination of mechanical strength, comfort, and aesthetic appeal, making them widely used in textile manufacturing. This study explores the properties of fabric samples woven from blended yarns, focusing on their mechanical characteristics, comfort parameters, and aesthetic attributes. Various fiber combinations were tested to evaluate tensile strength, elongation, air permeability, thermal resistance, and surface texture. The results provide insights into optimizing fiber blends for enhanced performance in textile applications.

**4.5 Performance Evaluation:**

After blending, the fabric samples were subjected to mechanical testing and comfort analysis, to determine the impact of fiber composition on fabric properties.

**4.5.1 Tensile Strength and Elongation**

Tensile strength and elongation are critical mechanical properties that determine the durability, flexibility, and overall performance of textile materials. In this study, the tensile strength and elongation of the blended stinging nettle-Nylon 6,6 fibers were analyzed to evaluate the effects of fiber composition on fabric resilience and stretchability. The tensile strength and elongation of pure stinging nettle, pure Nylon 6,6, and their blended fabrics (70:30 and 50:50 ratios) were tested using a Universal Testing Machine (UTM). The testing followed the ASTM D5034 standard for woven textiles and the ASTM D638 standard for fiber-reinforced composites. Fabric samples were cut into standard dog-bone or rectangular strips to ensure uniform testing. Samples were conditioned at 65% relative humidity and 21°C for 24 hours before testing. A constant rate of extension (CRE) tensile tester was used for precise results. Each sample was clamped at both ends and subjected to a gradually increasing load until breakage occurred. The force at rupture (breaking load) was recorded. Elongation at break was measured as the percentage increase in fabric length before failure. Average values from multiple trials were used for analysis.

**4.5.2 Fabric Air Permeability** – Fabric air permeability refers to the ability of air to pass through the textile material, measured in $cm^3/cm^2/s$ or $L/m^2/s$. It is a crucial parameter influencing breathability, thermal regulation, comfort, and moisture management in textiles. High air permeability enhances ventilation, making the fabric cooler and more comfortable, whereas low air permeability improves wind resistance and insulation for protective and winter wear.

In this study, the air permeability of pure stinging nettle, pure Nylon 6,6, and their blended fabrics (70:30 and 50:50 ratios) was analyzed to assess the effect of fiber blending on breathability and overall comfort. The fabric air permeability was tested using an Air Permeability Tester, following the ASTM D737 and ISO 9237 standards. Fabric samples were conditioned at 21°C temperature and 65% relative humidity for 24 hours before testing. Circular specimens of 20 $cm^2$ were cut from each fabric type. Samples were mounted in a test chamber to ensure uniform airflow measurement. A controlled air pressure was applied to one side of the fabric. The volume of air passing through per unit area was recorded. Multiple measurements were taken at different locations on the fabric to ensure accuracy.

## 5. Results and Discussion

### 5.1 Tensile strength

Tensile strength is a key method for assessing fabric strength and is widely regarded as an essential characteristic of textile fabrics. It measures the fabric's cohesion, and without adequate coherence, other properties hold little significance. The results provide the average load at break in N and elongation at break in mm, as reported in Table 1.

**Table 1: Tensile strength of Fabrics**

| S.No. | Blend Ratio | Load at peak (N) | | | | Elongation (mm) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 10 Ne | | 13 Ne | | 10 Ne | | 13 Ne | |
| | | Warp | Weft | Warp | Weft | Warp | Weft | Warp | Weft |
| 1 | 50SN/50N | 325.4 | 286.4 | 294.6 | 326.4 | 29.13 | 29.54 | 30.14 | 30.45 |
| 2 | 30SN/70N | 364.9 | 302.4 | 301.4 | 339.8 | 41.57 | 37.45 | 39.57 | 41.42 |
| 3 | 100N | 456.3 | 354.1 | 445.7 | 475.1 | 46.65 | 42.5 | 49.65 | 58.19 |

Table 1 reveals that, among the blended fabrics made from 10 Ne yarns. As the percentage of nylon 6,6 fiber increased from 30% to 70%, tensile strength consistently rose. The 100% nylon 6,6 fabric exhibited the highest tensile strength among all the fabrics tested. A similar trend was observed for fabrics made from 13 Ne yarns. In fabrics made from 10 Ne yarns, the tensile strength was higher in the warp direction than in the weft direction, while the opposite trend was seen in fabrics made from 13 Ne yarns.

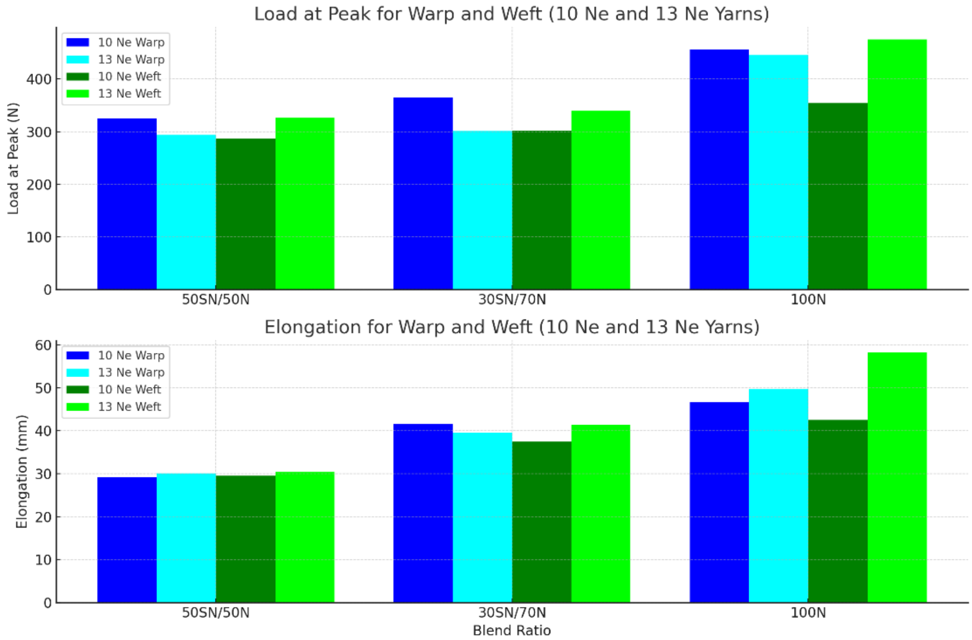


**Fig.1: Tensile strength of Fabrics**

## 5.2 Comfort and Aesthetic Properties

### 5.2.1 Fabric Air Permeability

Air permeability refers to the rate of air flow through a fabric under a differential pressure across its surfaces. Fabrics with a higher percentage of nettle fiber exhibit better air permeability compared to those with a higher proportion of acrylic fiber.

As shown in Table 4.20, among fabrics made from 10 Ne yarn, blend had the highest air permeability, followed by the 50SN/50N and 30SN/70N blends, respectively. Similarly, for fabrics made from 13 Ne yarn, the 50SN/50N blend demonstrated the highest air permeability, followed by the 30SN/70N blend. According to Booth (1964), fabric cover significantly influences air permeability by altering the length of air flow paths through the fabric.

**Table: 2 Air Permeability of the fabric**

| S.No | Blend ratio | Air permeability (cc/sec/cm2) | |
|---|---|---|---|
| | | 10 Ne | 13 Ne |
| 1 | 50SN/50N | 50.46 | 54.36 |
| 2 | 30SN/70N | 46.35 | 50.12 |
| 3 | 100N | 42.15 | 42.16 |

The air permeability of fabrics made from 13 Ne yarns is higher than that of those made from 10 Ne yarns. One key factor influencing air permeability is yarn twist: as twist increases, the yarn's circularity and density rise, reducing the yarn diameter and enhancing the fabric's air permeability.

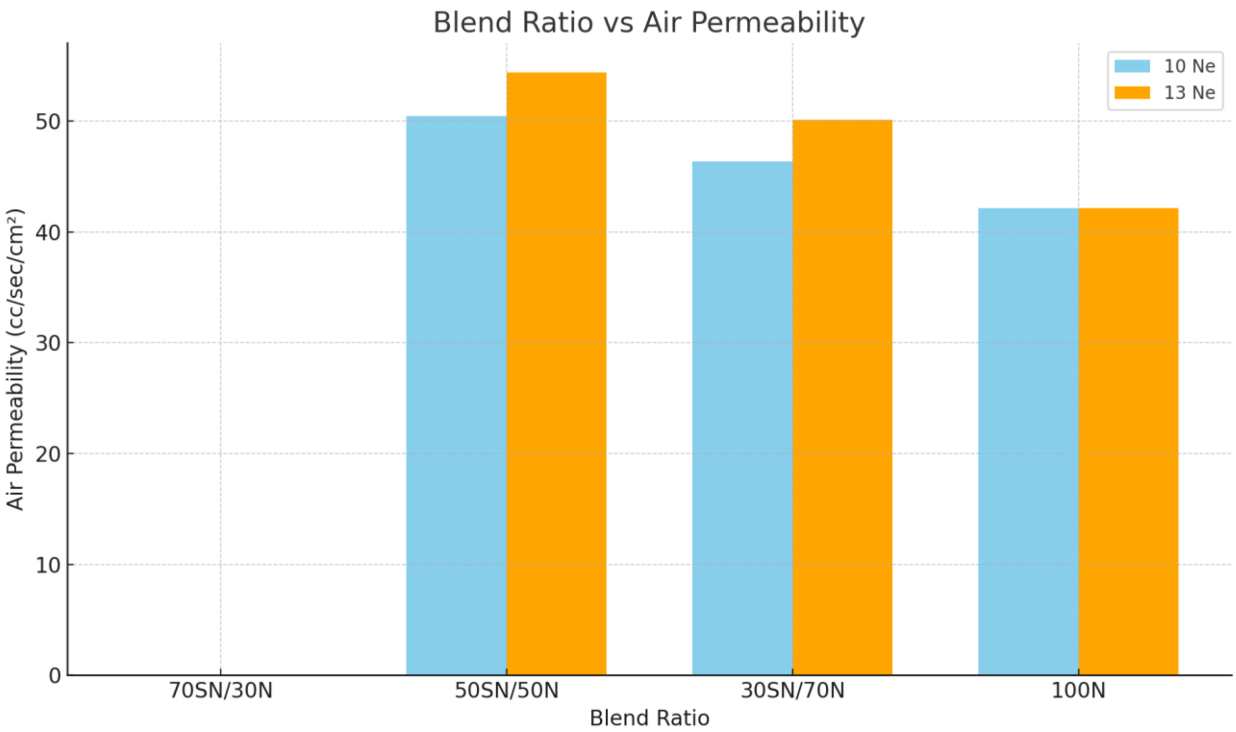


**Fig. 2: Air Permeability for different blend ratio**

Graph illustrating the air permeability (cc/sec/cm²) for different blend ratios at 10 Ne and 13 Ne. Each blend ratio is represented with two bars: one for 10 Ne and one for 13 Ne.

## 6. Conclusion

This study highlights the potential of fiber blending as a sustainable approach to enhancing textile performance. By combining stinging nettle, a strong and eco-friendly natural fiber, with Nylon 6,6, a durable and resilient synthetic fiber, the resulting hybrid fabrics exhibit improved tensile strength, elongation, durability, and breathability. The findings suggest that a 50:50 blend provides an optimal balance between strength and flexibility, while a 70:30 blend prioritizes sustainability while maintaining adequate mechanical properties.

The results demonstrate that fiber blending effectively integrates the advantages of natural and synthetic fibers, improving mechanical properties, comfort, and environmental impact. This approach reduces dependency on purely synthetic materials while enhancing the functional performance of textiles for diverse applications, including apparel, industrial textiles, and technical fabrics. This research underscores the significance of hybrid fiber technology in shaping the future of sustainable textiles, paving the way for eco-conscious, high-performance fabrics that cater to both industrial needs and environmental responsibility.

### Future Research Directions

To further advance sustainable textile innovations, future research should focus on:

- Bio-based synthetic alternatives: Exploring biodegradable and bio-derived polymers to replace conventional synthetics and minimize plastic waste.
- Circular economy practices: Developing recyclable fiber blends and closed-loop processing methods

to enhance material reuse.

- Advanced fiber treatments: Investigating surface modifications, nanotechnology, and sustainable dyeing methods to improve fabric properties while reducing environmental impact.
- Performance optimization: Studying additional fiber ratios, weaving techniques, and textile coatings to refine the balance between durability, comfort, and sustainability.

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