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Development and characterization of stinging nettle and Nylon 6, 6 blends for yarn production

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Abstract
The textile industry is continually evolving, driven by the demand for innovative and sustainable materials. This study explores the blending of nettle fiber and nylon fiber up to the yarn stage. Nettle fiber, known for its eco-friendly properties and durability, offers a sustainable alternative to traditional fibers. Nylon, a synthetic fiber, is renowned for its strength, elasticity, and resistance to abrasion. The blending of these fibers aims to combine the ecological benefits of nettle with the performance advantages of nylon. In this research, different blend ratios of nettle and nylon fibers are experimented with to determine the optimal mix that maximizes the strengths of both materials. The process involves the carding, combing, and spinning of the blended fibers to produce yarn. Various tests are conducted to assess the physical properties of the yarn, including yarn unevenness, yarn twist direction, single yarn strength and elongation. Additionally, the aesthetic qualities such as texture, appearance, and feel of the yarn are evaluated. The results indicate that a specific blend ratio enhances the overall performance of the yarn, providing a balance between sustainability and functionality. The study concludes with recommendations for the most effective blend ratios and potential applications in home furnishings and accessories, highlighting the advantages of using nettle-nylon blended yarns in creating durable, attractive, and environmentally responsible home textiles and daily lifestyle. This research contributes to the advancement of sustainable textile materials and offers practical insights for manufacturers aiming to produce high-quality home furnishing products and accessories foe daily life.

Keywords: Nettle fiber, Nylon fiber, blending, textile industry, sustainability, performance, hybrid textiles, eco-friendly, manufacturing, properties

1. Introduction
The demand for sustainable, high-performance fibers in textile production has increased significantly over the past decade. With a growing environmental consciousness, industries are seeking natural alternatives to synthetic fibers, aiming to reduce the negative environmental impact associated with fiber production. Among the natural fibers, nettle fiber has gained attention due to its eco-friendly nature and exceptional properties such as breathability, moisture management, and antimicrobial capabilities. On the other hand, synthetic fibers like nylon remain dominant in industries where high strength, elasticity, and resilience are required, especially in home furnishings and accessories.
This research aims to explore the development of blended yarns using nettle and nylon fibers to combine the sustainability of nettle with the strength and durability of nylon. The blend is intended for home furnishing applications and accessory materials where both aesthetic appeal and performance are crucial. The study examines the properties of the blend in comparison to pure nettle and pure nylon yarns, analyzing mechanical strength, thermal behavior, and aesthetic characteristics.

2. Literature Review
2.1. Nettle Fiber: A Sustainable Alternative
Nettle fiber is derived from the stem of the nettle plant, traditionally used in textiles across Europe and Asia. The fiber boasts several advantages such as biodegradability, low water consumption during cultivation, and resistance to pests, making it an environmentally sustainable choice.

Recent studies have focused on the mechanical properties of nettle fiber, indicating high tensile strength and elongation comparable to other natural fibers like flax and hemp.

2.2. Nylon Fiber: Strength and Durability
Nylon, a synthetic polyamide, was first developed in the 1930s and has since been a popular choice in various textile applications due to its strength, durability, and elasticity. It is highly resistant to abrasion, which makes it an ideal candidate for heavy-duty applications like upholstery. However, nylon's environmental impact, derived from petrochemical sources, remains a concern, spurring interest in developing fiber blends with natural materials.

2.3. Fiber Blending: Advantages and Applications
Fiber blending is a well-established practice in the textile industry used to achieve a balance of properties from different fibers. Blends can enhance fabric performance, such as improving elasticity, strength, or aesthetic appeal, while reducing costs or environmental impact. Several studies have shown that blending natural fibers with synthetic fibers can lead to materials with superior performance, suitable for high-stress applications like home furnishings.

3. Materials and Methods
3.1. Materials
- **Nettle fiber:** Nettle plants (Urtica dioica) are grown and harvested when they reach the right maturity for fiber extraction. These plants are typically harvested in late summer or early autumn when the fiber content in the stems is at its peak. The nettle stems are then subjected to processing methods to extract the fibers. This involves separating the bast fibers (located in the outer stem) from the woody core. Retting is a microbial or chemical process that breaks down the non-fibrous materials in the plant stems, such as pectin, that hold the fibers together. It can be done by exposing the stems to moisture (such as soaking them in water) to allow natural bacterial processes to loosen the fibers, making them easier to extract. After retting, the nettle fibers are cleaned, combed, and spun into yarn using traditional or industrial spinning techniques. The fibers are twisted to form a continuous yarn, which can then be woven or knitted into textiles. This entire process aims to produce high-quality, eco-friendly yarn from nettle fibers that can be used for various textile applications, including the production of yarn for home furnishings and accessories.
- **Nylon fiber:** Nylon is a synthetic polymer, specifically a type of polyamide, created through chemical processes. The term "commercial-grade" refers to nylon fibers that are produced on a large scale for industrial use, adhering to standardized specifications for performance and quality. Nylon is known for its exceptional tensile strength, making it ideal for applications requiring durable and long-lasting materials. It can withstand high stress without breaking, which is a crucial property for textiles in heavy-use applications, such as home furnishings and accessories. Another key property of nylon is its elasticity, meaning it can stretch under tension and return to its original shape without permanent deformation. This property enhances the flexibility and resilience of blended yarns, improving comfort, durability, and shape retention in the final product. Nylon's combination of strength and elasticity makes it a valuable component when blended with natural fibers like nettle to create yarns that offer both durability and aesthetic appeal in home furnishings.
- **Blends:** Blends of nettle and nylon were created in various ratios (i.e, 50:50, 70:30, 30:70) to evaluate the influence of fiber composition on yarn properties.

3.2. Yarn Production
The fibers were blended using conventional spinning techniques. Blending ratios were carefully controlled to ensure consistency in the yarn structure. The yarn was produced using a ring-spinning machine, ensuring even twist and tension distribution across the yarn length. Each blend was characterized for its yarn count and twist per inch (TPI).

3.3. Characterization Techniques
The physical and mechanical properties of the nettle-nylon blended yarns were evaluated using standardized testing methods:
The blending of nettle with nylon 6,6 aimed to optimize the properties of nettle fiber while compensating for its limitations, such as its harsh texture and stiffness. This approach also enabled the creation of unique products, enriching market offerings. Blended yarns with counts of 10 Ne and 13 Ne were successfully produced, along with pure nylon 6,6 yarns as reference samples. However, producing a 13 Ne yarn with a 70SN/30N blend was not feasible due to excessive breakage in the nettle fibers. Pure nettle yarn was only produced in 7 Ne on the carding machine because its brittle nature led to significant breakage, preventing the formation of higher-count yarns.

Table 1: Properties of Pure Nettle Yarns

S. No	Parameters	Mean Value	CV %
1.	Yarn Count (Ne)	2.4	8.99
2.	Twist per inch	10.75	11.05
3.	Breaking Force (kg)	634.0	51.02
4.	Elongation at break (mm)	2.67	46.90
5.	Tenacity (g/tex)	4.00	52.35

4. Results and Discussion
4.1 Yarn Count
Yarn count represents the fineness of yarn, which directly influences fabric thickness. It was measured using the Ne system, an indirect yarn numbering method where higher numbers indicate finer yarns (Hollen and Saddler, 1973).

Table 2: Yarn Count Blended Yarns

S. No	Blend Ratio	Yarn count (Ne)	
		10 Ne yarn	13 Ne yarn
1.	70 SN /30 N	-	-
2.	50 N /50 N	15.24	24.66
3.	30 SN /70 N	19.06	29.83
4.	100 N	22.78	32.53

SN = Stinging Nettle, N = Nylon

Table 2 shows that, 100% nylon 6,6 yarns exhibited higher yarn counts compared to blended yarns. The yarn count consistently decreased as the proportion of nettle fiber increased in each nylon 6,6 blend, resulting in thicker yarns after blending nettle with nylon 6,6 fibers.

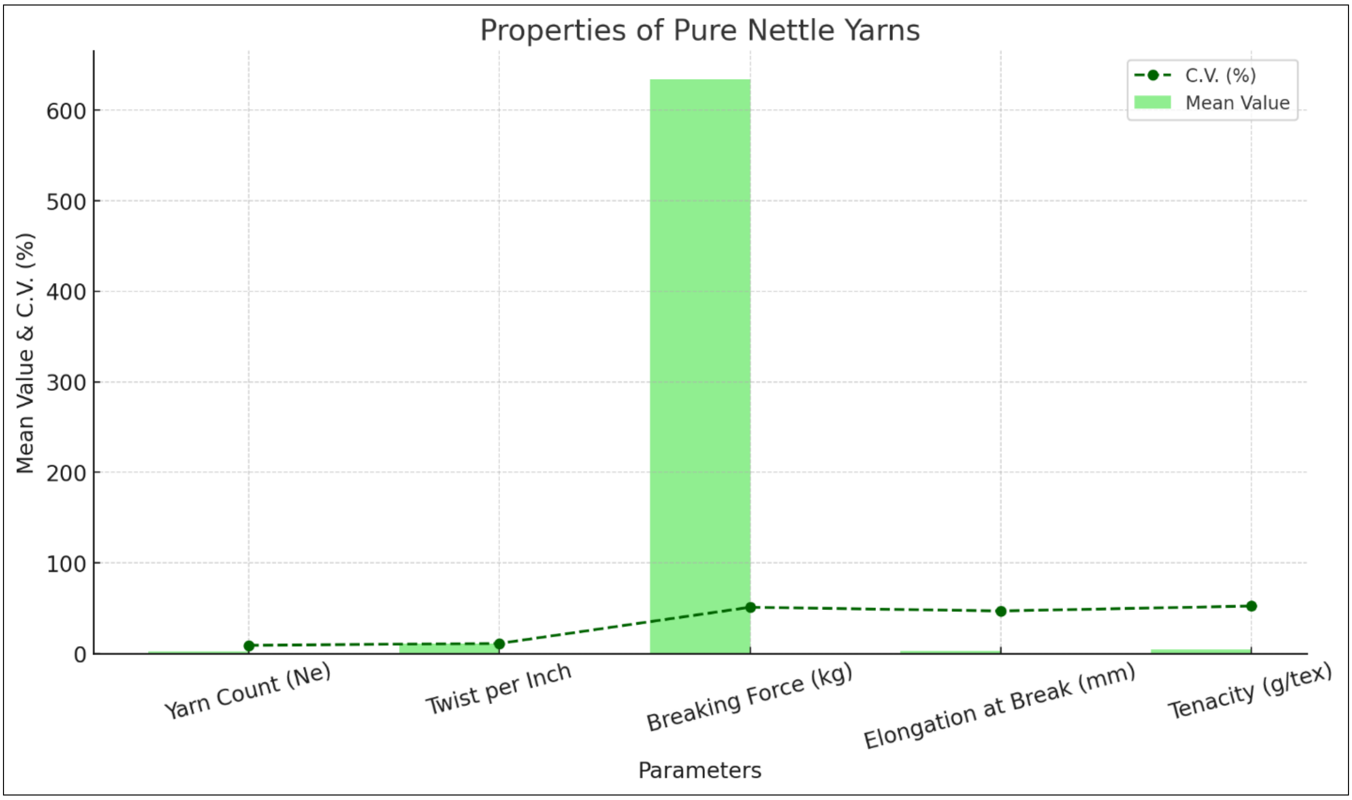

Fig 1: Properties of pure Stinging Nettle fiber

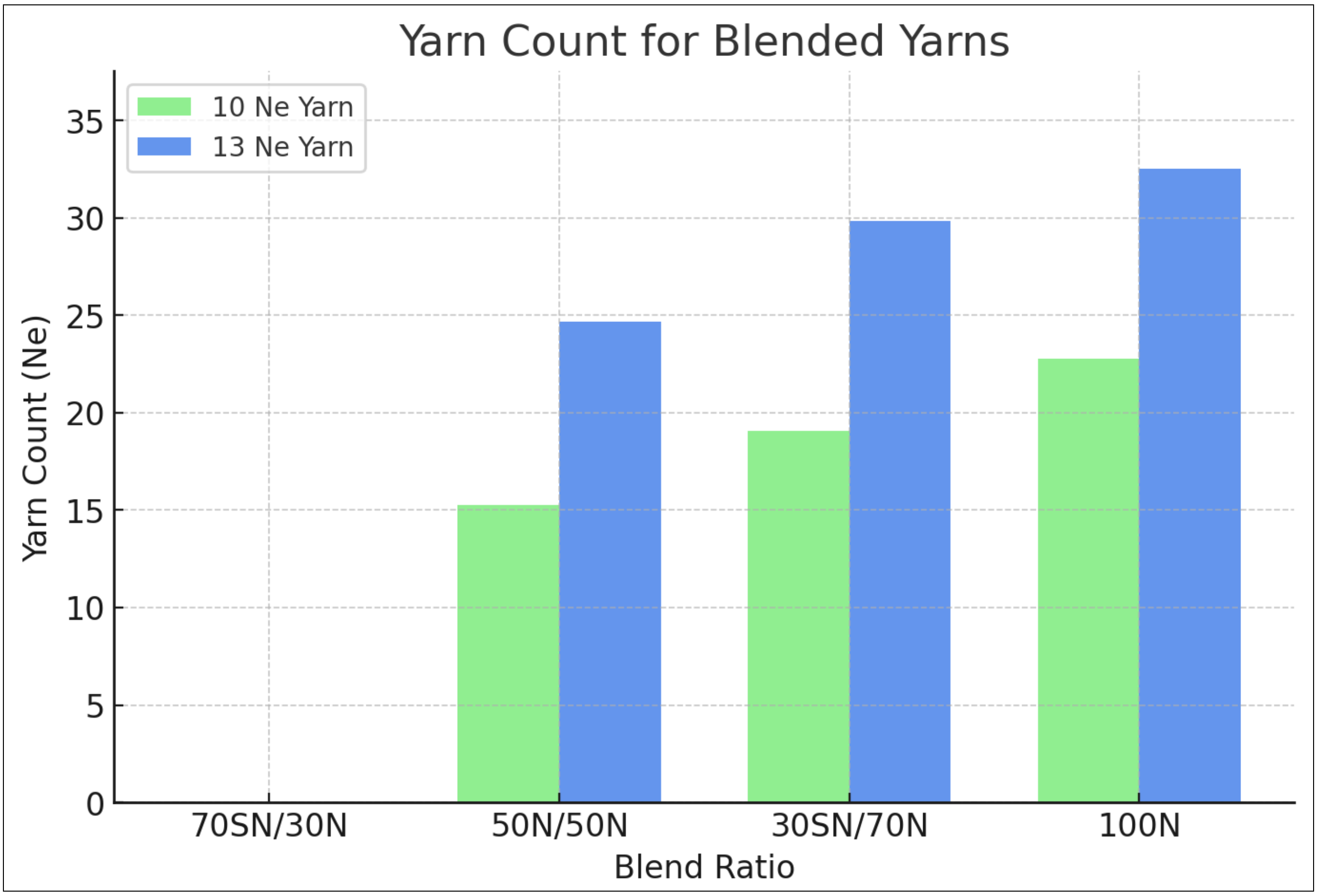

Fig 2: Yarn count of Blended Yarn ratio

Twist in Yarn

Yarn twist is a critical morphological feature that greatly influences yarn properties, such as breaking strength, and plays a significant role in its processing.

Table 3: Amount of Twist in Blended Yarns

S. No.	Blend Ratio	10 Ne		13 Ne		Direction of Twist
		Twist (Turns/inch)	C.V (%)	Twist (Turns/inch)	C.V (%)	
1.	70 SN /30 N	-	-	-	-	-
2.	50 SN /50 N	14.27	8.14	18.25	6.55	Z
3.	30 SN /70 N	12.93	4.75	18.00	7.91	Z
4.	100 N	10.09	6.10	11.20	6.11	Z

Table 3 shows that the twist per inch (TPI) of pure 10 Ne nettle yarn was 10.75. According to Table 1, the TPI in 10 Ne blended yarn ranged from 12. 93 to 14.27, while in 13 Ne blended yarn it ranged from 18.00 to 18.25. There was minimal variation in TPI among blended yarns of the same count.

The difference in TPI between 10 Ne and 13 Ne yarns can be attributed to the relationship between twist and yarn thickness, where thinner yarns require a higher twist to achieve the desired effect (Basu, 2001).

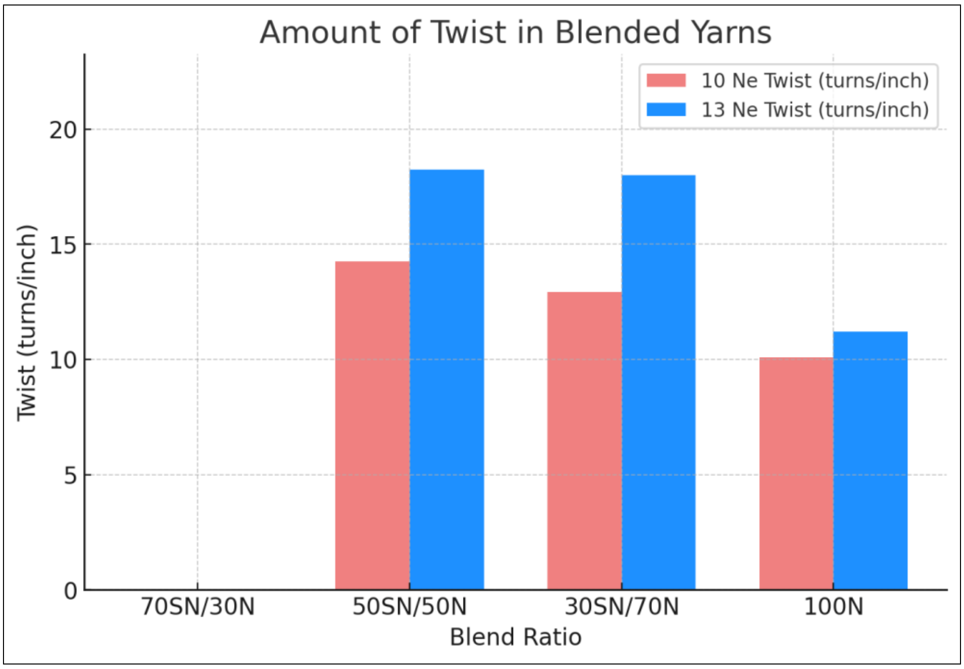

Fig 3: Amount of twist in blended yarns

Here is a figure illustrating the amount of twist (in turns per inch) and the coefficient of variation (C.V. %) for different blend ratios in 10 Ne and 13 Ne yarns.

Yarn Strength

Strength is a crucial characteristic of yarn as it directly affects the overall strength of the fabric. Single yarn tenacity and elongation were tested, and the results, presented as mean values. The tenacity of pure nettle yarn was the lowest. Among 10 Ne yarns, the 70SN/30N blend had the lowest tenacity. As the proportion of nylon 6,6 fiber increased from 30% to 70%, the tenacity of the yarns also improved, a pattern similarly observed in 13 Ne yarns.

Table 4: Strength characteristics of Blended Yarns

S. No.	Blend Ratio of Yarns	Parameters					
		Breaking Force (kg)	CV (%)	Elongation at Break (mm)	CV (%)	Tenacity (g/tex)	CV (%)
10 Ne							
1	70SN /30N	-	-	-	-	-	-
2	50SN /50N	424.9	19.4	13.82	32.09	13.04	17.04
3	30SN/70N	729.6	30.9	18.09	23.92	17.55	7.1
4	100 N	689.3	4.2	26.83	6.6	16.30	6.59
13 Ne							
5	50SN /50N	235.02	26.50	10.62	25.09	10.01	27.02
6	30SN/70N	297.75	18.00	13.09	22.00	10.5	17.09
7	100N	739.80	8.69	24.00	6.02	14.6	7.08

Tables 4 reveal that 100% nylon 6,6 yarn exhibited the highest elongation. As the proportion of nettle fiber increased in blended yarns, elongation at break decreased, a trend consistent in both 10 Ne and 13 Ne yarns.

The results for yarn breaking strength and elongation clearly indicate that yarn strength, elongation, and tenacity values declined with an increase in nettle fiber content, despite nettle fibers being stronger than nylon 6,6. This can be attributed to the fact that when fibers are blended, the resulting strength is not simply the algebraic sum or average of the individual fiber strengths. The lower strength of blended yarns is primarily due to the difference in the breaking elongation of the

component fibers (Bhattacharya, 2001).
Grover and Hamby (1988) noted that numerous inherent variables influence the final strength of spun yarn. Salhotra (2004) highlighted that many researchers have studied the tenacity of blended yarns, consistently finding that blended yarn strength is lower than the average strength calculated from the individual strengths and proportions of the component fibers.
The reduced strength of blended yarns with a higher nettle content can be attributed to several factors. One key reason is the brittle nature of nettle fibers, which made it impossible to produce 100% nettle yarn for 10 Ne and 13 Ne counts. Additionally, yarns with a higher nettle fiber percentage were more uneven, with a greater number of imperfections that negatively affected strength. This aligns with Grover and Hamby's (1988) assertion that greater uniformity in spun yarn results in higher strength, while more uneven yarns are weaker. Booth (1968) emphasized that thin spots in slivers, roving, or yarns act as weak points, increasing the likelihood of breakage. Similarly, Kothari (1999) stated that less regular yarns are weaker due to thinner, weaker regions caused by irregularity.

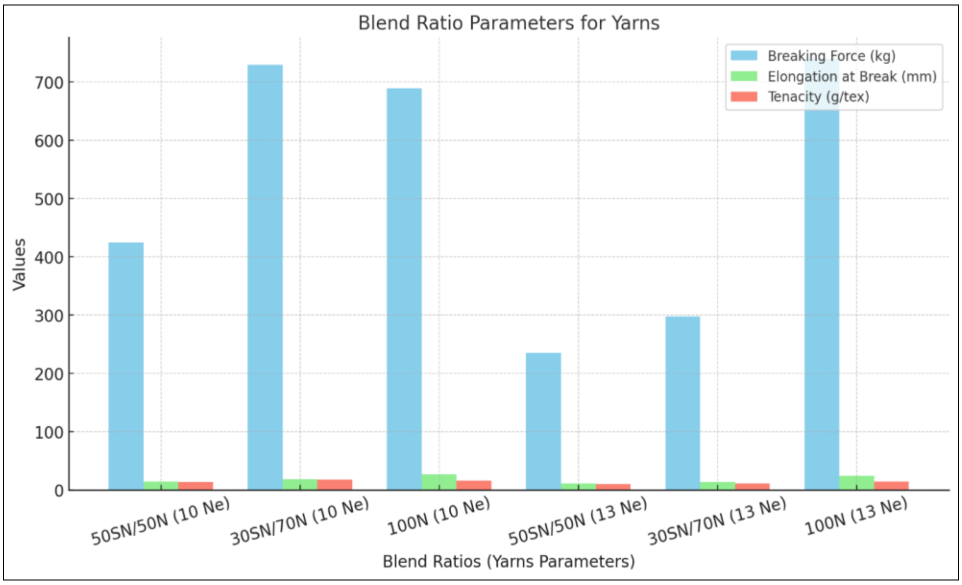

Fig 4: Ratio parameter of blended yarns

Yarn Unevenness and Imperfection

Yarn unevenness plays a crucial role in determining both the weavability and the visual appearance of fabric (Salhotra, 2004). The mean values of yarn unevenness and imperfections are provided in Tables 4.
It is evident that among the 10 Ne yarns, the 70SN/30N blend exhibited the highest unevenness, as compare to 50SN/50N and 30SN/70N blends. Similarly, the 100% nylon 6,6 yarn demonstrated the lowest unevenness at 8.24%. The greater unevenness observed in yarns with higher nettle fiber content can be attributed to the increased number of imperfections. This is likely due to the significant variation in the fineness and length of nettle fibers, which are naturally occurring.

Table 5: Percent Unevenness and Imperfections in Blended Yarns

S. No.	Blend Ratio	Unevenness (%)	Thick Places (+50%)	Thin Places (- 50%)	Neps (+200%)
1	70 SN /30 N	-	-	-	-
2	50 SN /50 N	16.23	223.09/km	250.0/km	713/km
3	30 SN /70 N	13.12	108.05/km	95.7/km	326/km
4	100N	8.24	10.4/km	2.6/km	27.09/km

Table 5 clearly shows a similar trend across all 13 count yarns. Blended yarns with a higher proportion of nettle fibers exhibited greater unevenness. The 50SN/50N blend recorded the highest unevenness along with the maximum number of thick places, thin places, and neps. In contrast, the 100% nylon 6,6 yarn demonstrated the lowest values, with 8.24% unevenness, 10.4 thick places/km, 2.6 thin places/km, and 27.09 neps/km.
The 30SN/70N yarn, containing a lower percentage of nettle fibers, exhibited 13.12% unevenness, 108.05 thick places/km, 95.7 thin places/km, and 326 neps/km. While these values were higher than those of the 100% nylon 6,6 yarn, they remained lower compared to the 50SN/50N blend.
The bar graph illustrating the percent unevenness and imperfections in blended yarns across different blend ratios.
Grover and Hamby (1998) emphasized that numerous factors contribute to yarn evenness, while Booth (1968) identified causes of irregularity, including raw material properties, inherent limitations in the spinning process, external factors, and operational inefficiencies.

Yarn Hairiness

The mean values of yarn hairiness are reported in Table 6.
Table 6 indicates that for 10 Ne blended yarns, the highest hairiness was observed in the 70SN/30N blend, while the lowest hairiness was found in the 30SN/70N blend.
For 13 Ne blended yarns, Table 6 shows that the 50SN/50N blend had the highest hairiness, whereas the 30SN/70N blend recorded the lowest hairiness at 10.62. The maximum coefficient of variation, 1.2 percent, was also observed in the 30SN/70N blend, mirroring the trend seen in 10 Ne yarns.

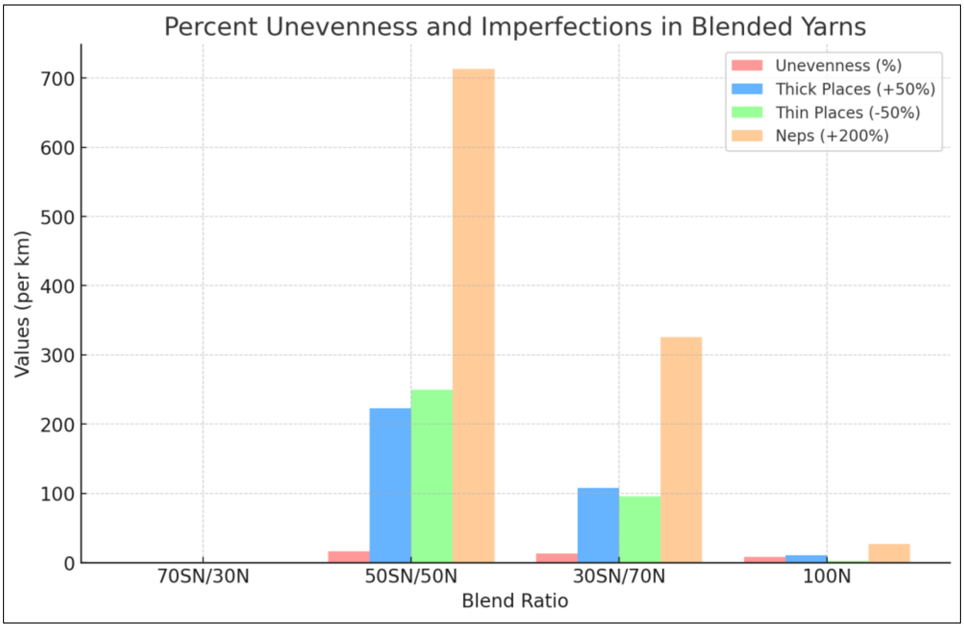

Fig 5: Percent unevenness & Imperfections in blended yarns

Table 6: Hairiness Value of Blended Yarns

S. No	Blend Ratio	Hairiness Value	C.V (%)
		10 Ne	
1	70 SN /30 N		
2	50 SN /50 N	15.49	0.9
3	30 SN /70 N	13.65	1.5
4	100 N	11.0	0.5
		13Ne	
5	50 SN /50 N	11.25	3.0
6	30 SN /70 N	10.62	1.2
7	100 N	9.04	0.5

Based on the results, it can be concluded that the hairiness value increased with a higher percentage of nettle fiber in the blend ratios. This may be due to the coarse nature of nettle fibers, which tend to migrate to the yarn's periphery, while finer fibers remain at the core. Hollen and Saddler (1973) noted that long, fine fibers typically move to the center of a yarn, whereas coarse, shorter fibers migrate toward its periphery.

Graph illustrates that for each blend ratio, yarn samples of 10 counts exhibited higher hairiness values. This can be attributed to the greater number of fibers in the cross-section of 10 Ne yarns. With more fibers present, there is a higher tendency for fibers to move outward during drafting at the ring frame due to reduced control.

Similar findings were reported by Basu (2001) and Salhotra (2004), who observed that hairiness depends on the number of fibers in the cross-section. Coarser yarns tend to have more hairs than finer yarns.

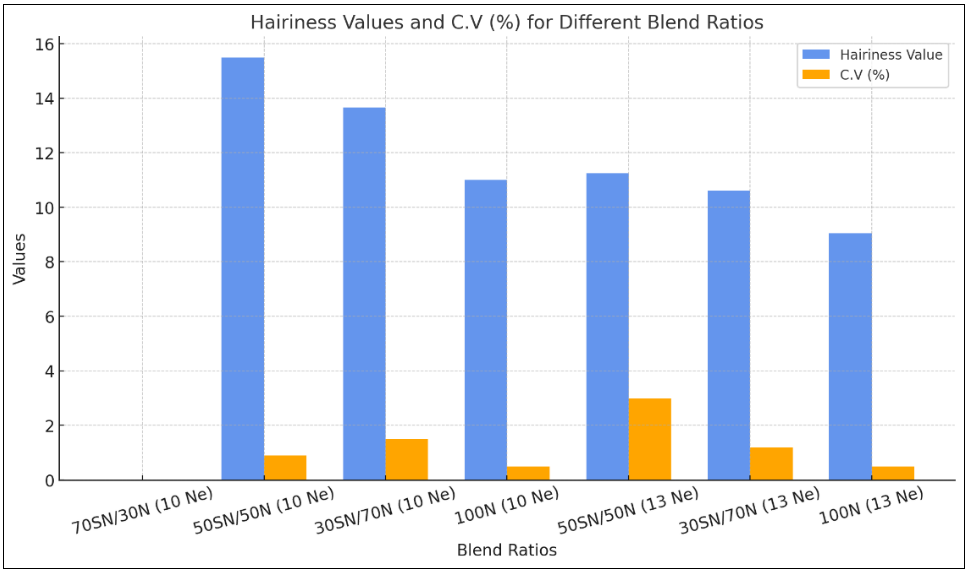

Fig 6: Hairiness for blended yarns

The bar graph depicting the Hairiness Value and C.V. (%) for blended yarns across different blend ratios and yarn counts.

Another possible reason for the higher hairiness in 10 Ne yarns is the lower number of turns per inch compared to 13 Ne yarns. Twist plays a crucial role in binding fibers together, making the yarn more compact. A higher number of turns per inch can therefore reduce hairiness. This aligns with Basu's (2001) observation that increasing yarn twist tends to decrease certain hairiness parameters. Similarly, Barella (1999) highlighted that yarn hairiness is strongly influenced by twist, with hairiness generally decreasing as twist increases.

5. Conclusion

The development of nettle-nylon fiber blends offers a promising solution for the home furnishing industry, combining the sustainability of nettle with the strength and durability of nylon. The results show that by adjusting the blend ratio, it is possible to optimize the mechanical, thermal, and aesthetic properties of the yarns for specific applications. The 50:50 and 70:30 nettle-nylon blends demonstrated superior characteristics, particularly in terms of tensile strength, thermal stability, and moisture management, making them suitable for high-performance home furnishing applications like upholstery, curtains, and decorative textiles.

Further research could explore the environmental impacts of nettle fiber cultivation and the recyclability of nettle-nylon blends. Additionally, the incorporation of bio-based synthetic alternatives to nylon could further enhance the sustainability profile of the blends.

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