A Study on the Structural and Tensile Behaviour of Tasar and Eri Spun Silk Yarns

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Publication Date: 2025/07/22

Abstract: This study investigates the structural and tensile characteristics of spun silk yarns produced from two wild silk varieties—Tasar (*Antheraea mylitta*) and Eri (*Samia ricini*)—with the objective of evaluating their performance and inter-parameter relationships. Given the growing demand for sustainable and eco-friendly textiles, a detailed analysis of yarn geometry and mechanical Behaviour was undertaken to better understand the suitability of these fibers for high-value applications. Spun yarns of 60 Nm count were prepared from degummed pierced Tasar and cut Eri cocoons using standardized cotton system spinning techniques. A range of parameters, including linear density, yarn diameter, twist per meter, surface twist angle, contraction and retraction factors, and tensile properties (count strength product, single yarn tenacity, and elongation), were systematically evaluated.The results revealed that Eri yarns exhibited more consistent structural properties and superior tensile performance compared to Tasar yarns, with lower variability across key parameters. Tasar yarns demonstrated higher twist levels and contraction values, contributing to greater compactness but lower mechanical strength. Statistical analysis confirmed significant differences between the two yarn types, with correlation studies highlighting strong positive associations among CSP, tenacity, and elongation, while twist negatively influenced tensile Behaviour. These findings underscore the critical influence of fiber morphology and yarn structure on the mechanical properties of wild silk yarns. The study offers valuable insights for process optimization, quality enhancement, and the expanded application of Tasar and Eri yarns in sustainable textile development.

Keywords: *Eri Spun Silk Yarns, Structural Properties, Tasar Spun Silk Yarns, Tensile Properties.*

How to Cite: Rahul Ranjan Ghosh; Suhasini B; Sateesh Kumar; Sumit Kumar (2025), A Study on the Structural and Tensile Behaviour of Tasar and Eri Spun Silk Yarns. *International Journal of Innovative Science and Research Technology*, 10(7), 1645-1653. https://doi.org/10.38124/ijisrt/25jul1109

I. INTRODUCTION

Silk is a naturally occurring protein-based filament fiber that has long been esteemed for its remarkable combination of aesthetic appeal, tactile softness, mechanical strength, and biodegradability. India plays a pivotal role in the global silk industry and holds the unique distinction of being the only country that produces all four commercially significant varieties of silk—Mulberry, Tasar, Eri, and Muga. While Mulberry silk accounts for the majority of the country's silk output and enjoys widespread commercial usage, Vanya silks, a collective term for wild silks such as Tasar (*antheraea mylitta*) and Eri (*samia ricini*), hold immense socio-economic and ecological significance, particularly among tribal and forest-dependent communities [1-2].

Unlike Mulberry silk, which is traditionally reeled as a continuous filament from intact cocoons harvested before the emergence of the moth, Eri silk is inherently non-reelable due to its open-ended cocoon structure. As a result, it is processed exclusively into spun silk yarns, utilizing staple fibers extracted from the degummed cocoons. Tasar silk, in contrast, is predominantly reelable; however, a considerable proportion of the harvest—comprising pierced cocoons (from which the moth has naturally emerged) and pelade waste (residual silk left in cocoons after reeling)—is unsuitable for reeling. These by-products of the reeling process lack filament continuity and therefore cannot be processed into reeled silk [3-4]. Nevertheless, they are highly suitable for spun silk production. In the case of Tasar and Eri, the pierced or cut cocoons are first degummed to remove sericin, the gummy coating surrounding the fibroin fibers. This process yields short-staple silk fibers, which are then subjected to a series of preparatory steps including opening, carding, combing, drawing, and spinning, depending on the desired yarn properties and the spinning system employed—typically cotton or worsted systems. The inherent variability in fiber length, diameter, and morphology—characteristic of wild silks—adds complexity to the spinning process but also contributes to the textural uniqueness and environmental appeal of the final yarn. This combination of traditional knowledge, biological variability, and modern processing makes Tasar and Eri spun silk yarns an important area of research, particularly in the context of sustainable material innovation, rural employment generation, circular economy applications, and value addition to silk waste. As global demand grows for environmentally responsible and ethically sourced textiles, understanding and optimizing the production and performance of wild silk spun yarns becomes increasingly significant—both scientifically and socio-economically [5].

The spun silk yarns produced from Tasar and Eri fibers exhibit significant structural variability, largely due to the inherent irregularities in the raw material. Factors such as variability in fiber diameter and length, differences in degumming efficiency, staple length distribution, and the coarser, more fibrillated surface texture of wild silk fibers contribute to this inconsistency [6-7]. These fibers, unlike the fine and uniform filaments of Mulberry silk, present greater challenges during spinning process, often resulting in yarns with uneven packing density, twist irregularities, and fluctuations in cross-sectional dimensions. In the domain of textile engineering, yarn geometry—encompassing parameters such as yarn diameter, cross-sectional shape and uniformity, twist level, packing density and contraction—is a critical determinant of both yarn performance and fabric quality. These geometric characteristics directly influence the mechanical behaviour of yarns [8-9].

In the context of Tasar and Eri spun silk yarns, understanding and optimizing yarn geometry becomes particularly important due to the heterogeneous nature of the input fibers. The lack of uniformity in fiber properties can lead to significant deviations in yarn structure, which in turn affect key fabric properties. If the yarn geometry is poorly controlled, it can result in high variability in yarn strength, frequent end breakages during weaving, uneven fabric appearance, and a limited ability to meet the quality standards required for high-end applications. Consequently, a thorough analysis of yarn geometry in Tasar and Eri spun silk yarns is not only essential for quality control but also pivotal for enhancing product performance, process optimization, and expanding the market potential of these eco-friendly, value-added silk yarns in diverse textile sectors. Despite the significant socio-economic importance and the rising market demand for wild silks—particularly in the domains of sustainable fashion and technical textiles—there remains a noticeable gap in comprehensive scientific research focused on the yarn geometry of Tasar and Eri spun silk yarns. While several earlier studies have explored macroscopic yarn characteristics such as yarn count variation, tensile strength, and visual evenness, very few have investigated the micro-structural attributes that play a crucial role in determining yarn quality and performance. Key parameters such as yarn cross-sectional shape, twist distribution, fiber orientation, packing density, and compactness remain largely understudied, despite their direct influence on downstream processing and end-use fabric behaviour [10-12].

Given this context, a detailed geometrical analysis of Tasar and Eri spun silk yarns emerges as both a scientific imperative and a developmental priority. Understanding these micro-level structural features is essential for aligning the unique characteristics of wild silk fibers with the increasingly stringent performance requirements of modern textile applications. Furthermore, insights gained from this research will contribute to the formulation of best practices in wild silk spinning—particularly with regard to optimizing twist levels, enhancing fiber parallelization and packing, reducing hairiness, and improving yarn uniformity. Such advancements will not only elevate the quality and consistency of Tasar and Eri spun silk yarns but also expand their potential in high-value textile segments, thereby supporting sustainable livelihoods and promoting value addition in India's wild silk sector [13-14].

II. MATERIALS & METHOD

A. *Materials:*

Two types of wild silk waste materials were utilized for the preparation of spun silk yarns—Tasar and Eri. Unreelable/ pierced Tasar cocoon waste was procured from the Directorate of Sericulture (DoS), Chhattisgarh, while Eri cut cocoons were sourced from the Directorate of Sericulture (DoS), BTC, Kokrajhar, Assam.

B. *Preparation of Spun Silk Yarns*

The preparation of Tasar and Eri spun silk yarns involved a systematic, multi-stage process designed to convert degummed wild silk fibers into high-quality yarns suitable for diverse textile applications. As illustrated in the process flow diagram Fig. 1, the production steps included chemical pre-treatment, fiber opening and preparation, drafting, spinning, and post-spinning finishing operations. Each stage was optimized to preserve fiber integrity while achieving the desired yarn quality. For this study, 60 Nm spun silk yarns were prepared using both Tasar (T) and Eri (E) silk fibers, ensuring uniformity in count and process parameters for accurate comparative analysis.

C. *Testing Methods*

To evaluate the yarn geometry, a series of standardized tests were conducted. The spun silk yarns were conditioned at 21 ± 1°C and 65 ± 2% relative humidity for 24 hours before testing.

➢ *Assessment of Linear Density, Twist and Diameter*

Linear density was determined using the ASTM D1907/D1907M-12 standard, employing a wrap reel and analytical balance to calculate Yarn Metric Count (Nm) from a specified yarn length. Yarn diameter was measured following the CSTRI in-house method using an optical microscope with a calibrated eyepiece. Multiple cross-sectional images were analysed to obtain an average diameter, accounting for fiber irregularity. Twist per unit length was measured as per ASTM D1422/D1422M-13 using

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25jul1109

a twist tester by the direct untwist method, reporting values in turns per meter (TPM).

- *Analysis of Yarn Surface Twist Angle:*

The surface twist angle (θ) signifies the helical orientation of fibers around the yarn axis and is a critical parameter influencing the mechanical Behaviour, bulk, and aesthetic appearance of the yarn. In this study, the surface twist angle was calculated using the following mathematical relationship:

$$Tan\,\theta = \pi * D * T \quad .... (1)$$

Where:
θ = surface twist angle (in degrees),
D = yarn diameter (in mm),
T = twist per unit length (turns/mm).

- *Analysis of Yarn Contraction and Retraction:*

Twist is imparted to single yarns to enhance inter-fiber friction, minimize slippage, and improve cohesion. The twist direction is denoted by S and Z, indicating the angular orientation of the fibers. As fibers adopt a helical path during twisting, the yarn length contracts—this phenomenon is captured by measuring contraction and retraction. These parameters were determined using the following equations:

$$\text{Contraction Factor (Cy)} = \frac{L1}{L2} ...... (2)$$

$$\text{Retraction Factor (Ry)} = \frac{L1-L2}{L1} ...... (3)$$

Where:

L1 = Length of yarn in the untwisted (zero-twist) state

L2 = Length of yarn after twisting

The relationship between contraction and retraction factors is expressed as:

$$Cy = 1/(1 - Ry) \quad ...... (4)$$

- *Assessment of Lea Strength and Single Yarn Tensile Properties:*

The tensile properties of Tasar and Eri spun silk yarns, including single yarn strength, elongation, and lea strength, were assessed using a Universal Testing Machine. Single yarn tensile tests were conducted as per ASTM D2256-02, wherein individual yarns were subjected to uniaxial tension to determine breaking load and elongation, with load-elongation curves recorded for analysis. Lea strength, representing the collective strength of 120 yards, was evaluated following ASTM D1578-93.

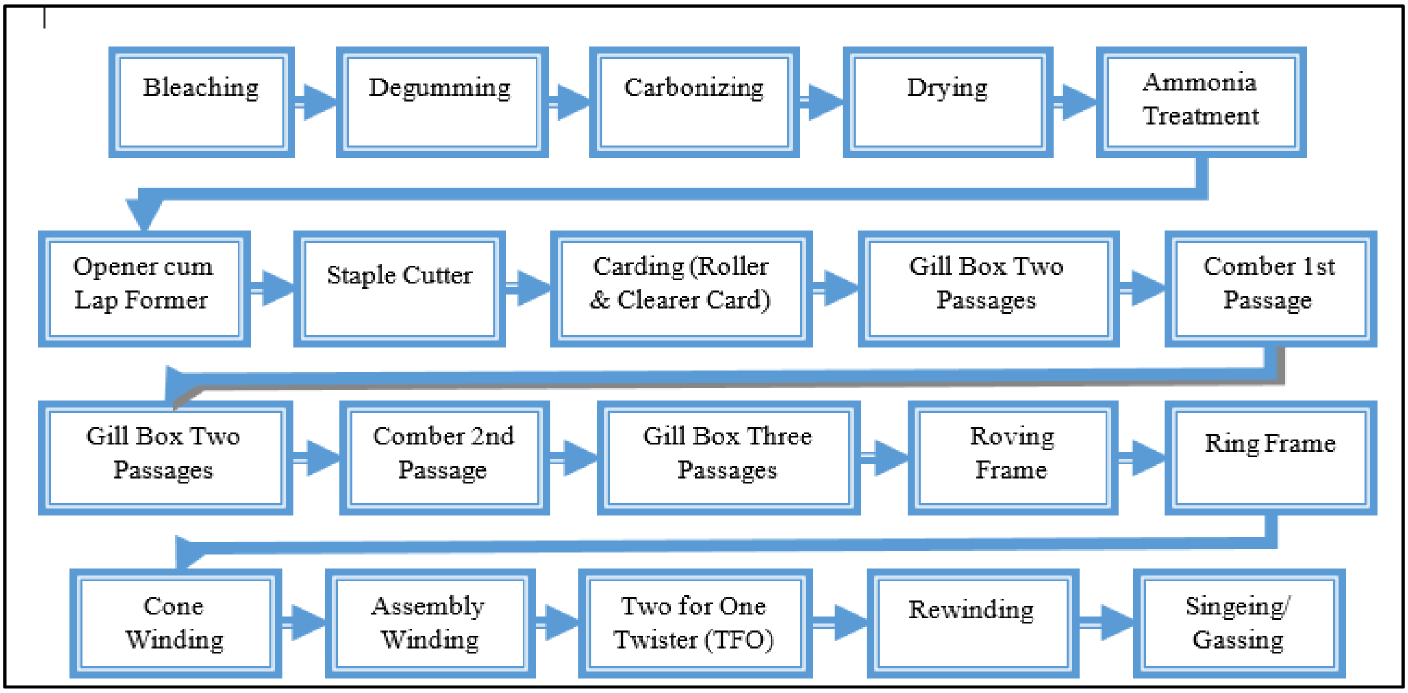

Fig 1 Process Flow Diagram for Tasar and Eri Spun Silk Yarn Preparation

III. RESULTS & DISCUSSION

A. *Determination of Structural Properties:*

The parameters used to assess the structural properties of Tasar and Eri spun silk yarns were summarized in Table 1, which included measurements of yarn diameter (mm), linear density (Nm), surface twist angle, and contraction and retraction factors. These parameters provided valuable insights into the yarns' geometric and structural characteristics, influencing their mechanical performance and suitability for textile applications.

- *Variation Between Nominal and Actual Linear Density:*

Figure 2 compared the nominal and actual linear density (Nm) values of Tasar and Eri spun silk yarns. Both yarn types were intended to be spun to a nominal count of 60 Nm. However, the actual measurements, as presented in Table 1, showed slight deviations from the target value. The mean

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25jul1109

actual linear density of Tasar yarns was 57.59 Nm, indicating a slightly coarser yarn, while Eri yarns recorded a value of 59.23 Nm, reflecting closer conformity to the nominal specification and suggesting better control over yarn fineness during spinning. This observation was further supported by the coefficient of variation (CV%), with Tasar yarns exhibiting a CV of 2.13% and Eri yarns showing a slightly lower CV of 2.02%, indicating greater uniformity in the Eri yarns.

➢ *Influence of Twist Per Meter (TPM) on Yarn Diameter:*

Figure 3 illustrated the relationship between twist per meter (TPM) and yarn diameter (mm) for Tasar and Eri spun silk yarns. The data clearly demonstrated an inverse correlation between twist level and yarn diameter. Tasar yarns, with a higher TPM of 820.4, exhibited a smaller average diameter of 0.1417 mm, whereas Eri yarns, which had a lower TPM of 685, displayed a larger mean diameter of 0.1634 mm. This trend suggested that higher twist insertion resulted in increased fiber consolidation, leading to a more compact yarn structure and reduced diameter. In contrast, yarns with lower twist levels tended to retain a bulkier cross-section, as seen in Eri yarns. The compactness in Tasar yarns could be attributed to enhanced fiber alignment and inter-fiber friction under higher twisting tension, which draws fibers closer toward the yarn axis, reducing the overall diameter. Additionally, the larger diameter of Eri yarns may be linked to the intrinsic properties of Eri fibers, including their higher crimp and bulk, which resisted compaction during twisting. This was further compounded by the lower twist level, which provided less torsional force to bind the fibers tightly together.

Table 1 Assessment of Structural Properties

#	**Diameter (mm)**		**Linear density (Nm)**		**Twist (TPM)**		**Surface Twist Angle**		**Contraction Factor**		**Retraction Factor**	
	Tasar	***Eri***	***Tasar***	***Eri***	***Tasar***	***Eri***	***Tasar***	***Eri***	***Tasar***	***Eri***	***Tasar***	***Eri***
1	0.1318	0.1288	55.36	59.82	796	836	18.24	18.69	1.06	1.04	0.06	0.04
2	0.1458	0.1405	56.96	60.92	850	730	21.26	17.85	1.04	1.02	0.04	0.02
3	0.1512	0.1352	57.05	60.02	890	628	22.90	14.93	1.09	1.01	0.08	0.01
4	0.1371	0.1371	57.03	59.14	742	670	17.71	16.09	1.02	1.02	0.02	0.02
5	0.1258	0.2219	55.22	59.04	820	618	17.94	23.30	1.04	1.01	0.04	0.01
6	0.1601	0.2138	55.03	58.39	874	674	23.72	24.34	1.06	1.02	0.06	0.02
7	0.1439	0.2166	58.54	59.39	812	676	20.15	24.69	1.06	1.01	0.06	0.01
8	0.1371	0.2138	56.97	62.61	896	688	21.09	24.79	1.03	1.00	0.03	0.00
9	0.1288	0.1288	57.74	59.56	810	638	18.14	14.47	1.05	1.09	0.05	0.08
10	0.1417	0.2050	57.55	57.63	768	608	18.87	21.38	1.04	1.04	0.04	0.03
11	0.1459	0.1505	58.43	60.02	722	696	18.30	18.21	1.08	1.02	0.07	0.02
12	0.1417	0.1682	58.62	57.96	732	648	18.04	18.89	1.10	1.03	0.09	0.03
13	0.1417	0.1547	59.02	58.92	910	676	22.04	18.18	1.04	1.02	0.04	0.02
14	0.1282	0.1593	57.78	58.34	924	734	20.41	20.17	1.02	1.01	0.02	0.01
15	0.1593	0.1552	57.94	57.93	764	684	20.92	18.44	1.04	1.06	0.03	0.06
16	0.1384	0.1547	59.21	58.91	806	826	19.30	21.87	1.05	1.02	0.05	0.02
17	0.1601	0.1459	58.59	58.96	798	724	21.86	18.35	1.03	1.03	0.03	0.03
18	0.1282	0.1513	58.21	60.45	808	692	18.02	18.20	1.06	1.05	0.06	0.05
19	0.1417	0.1414	57.98	58.12	848	674	20.67	16.66	1.05	1.03	0.05	0.03
20	0.1458	0.1454	58.65	58.39	838	580	20.99	14.83	1.06	1.04	0.06	0.04
Mean	0.1417	0.1634	57.59	59.23	820.40	685.00	20.03	19.22	1.05	1.03	0.05	0.03
Std Dev	0.01	0.03	1.23	1.20	58.65	63.95	1.83	3.24	0.02	0.02	0.02	0.02
CV %	7.35	19.43	2.13	2.02	7.15	9.34	9.13	16.87	2.01	1.97	39.42	67.94
Min	0.1258	0.1288	55.03	57.63	722.00	580.00	17.71	14.47	1.02	1.00	0.02	0.00
Max	0.1601	0.2219	59.21	62.61	924.00	826.00	23.72	24.79	1.10	1.09	0.09	0.08

➢ *Influence of Twist Level on Surface Twist Angle:*

Figure 4 presented the twist per meter (TPM) and corresponding surface twist angle (°) for Tasar and Eri spun silk yarns. The Tasar yarn exhibited a significantly higher twist level of 820.4 TPM compared to 685 TPM observed in the Eri yarn, indicating a tighter helical configuration in the Tasar yarn structure. This higher twist insertion likely enhanced inter-fiber cohesion and minimized fiber slippage. The surface twist angle, representing the angular orientation of fibers around the yarn axis, also followed a similar trend. Tasar yarn recorded a twist angle of 20.03°, whereas Eri yarn showed a slightly lower value of 19.22°. The higher twist angle in Tasar yarn was attributed to the greater twist insertion, which contributed to its compactness and structural uniformity. The differences in twist level and surface twist angle between Tasar and Eri yarns were likely influenced by variations in fiber morphology, frictional properties, and Behaviour during drafting and spinning. In terms of variation as shown in the Table 1, the coefficient of variation (CV%) for twist level was 7.15% in Tasar and 9.34% in Eri yarns, indicating relatively higher variability in twist for Eri. For surface twist angle, Tasar yarns exhibited CV% of 9.13, whereas Eri yarns showed a higher CV% of 16.87, suggesting greater inconsistency in fiber orientation within the Eri yarn structure.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25jul1109

➢ *Analysis of Contraction and Retraction Behaviour:*

Table 1 presented the statistical summary of yarn contraction and retraction factor for Tasar and Eri spun silk yarns. The mean contraction was slightly higher in Tasar yarns (1.05) than in Eri yarns (1.03), indicating that Tasar yarns tended to shorten more upon relaxation or finishing. Despite this difference, both yarn types exhibited relatively consistent contraction Behaviour, as reflected by their low coefficient of variation (CV%)—2.01% for Tasar and 1.97% for Eri—demonstrating good uniformity among the samples.

With regard to the retraction factor, Tasar yarns showed a higher mean value (0.05) compared to Eri yarns (0.03), suggesting that Tasar yarns experienced greater shrinkage after twist release. This observation was consistent with the higher twist per meter (TPM) recorded for Tasar yarns, which likely stored more torsional energy during spinning. However, the CV% for retraction was considerably high for both yarn types—39.42% for Tasar and 67.94% for Eri—indicating significant variability in the extent of retraction, especially in Eri yarns.

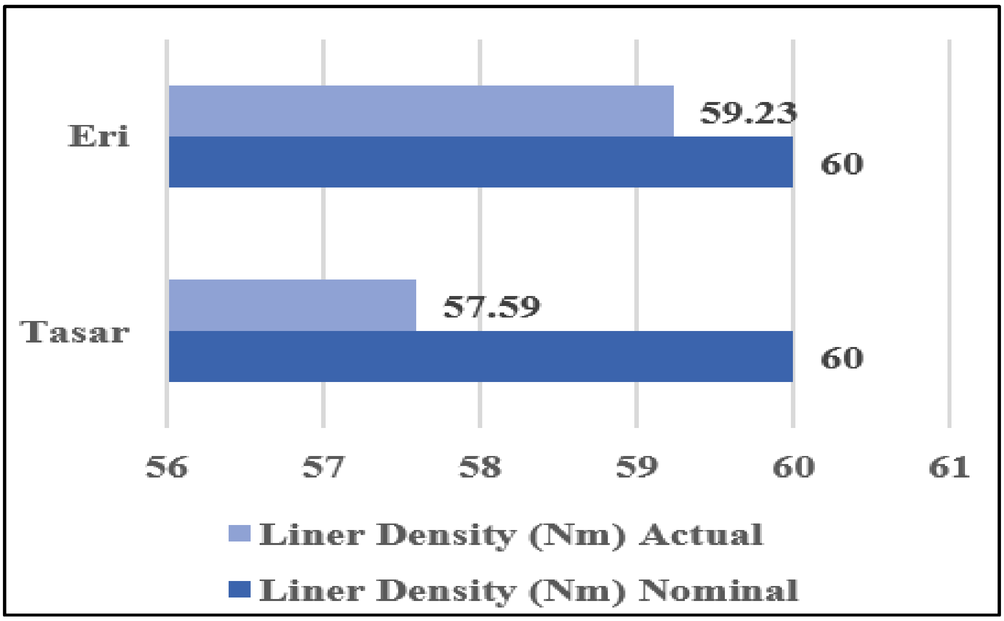

Fig 2 Nominal vs Actual Linear Density (Nm)

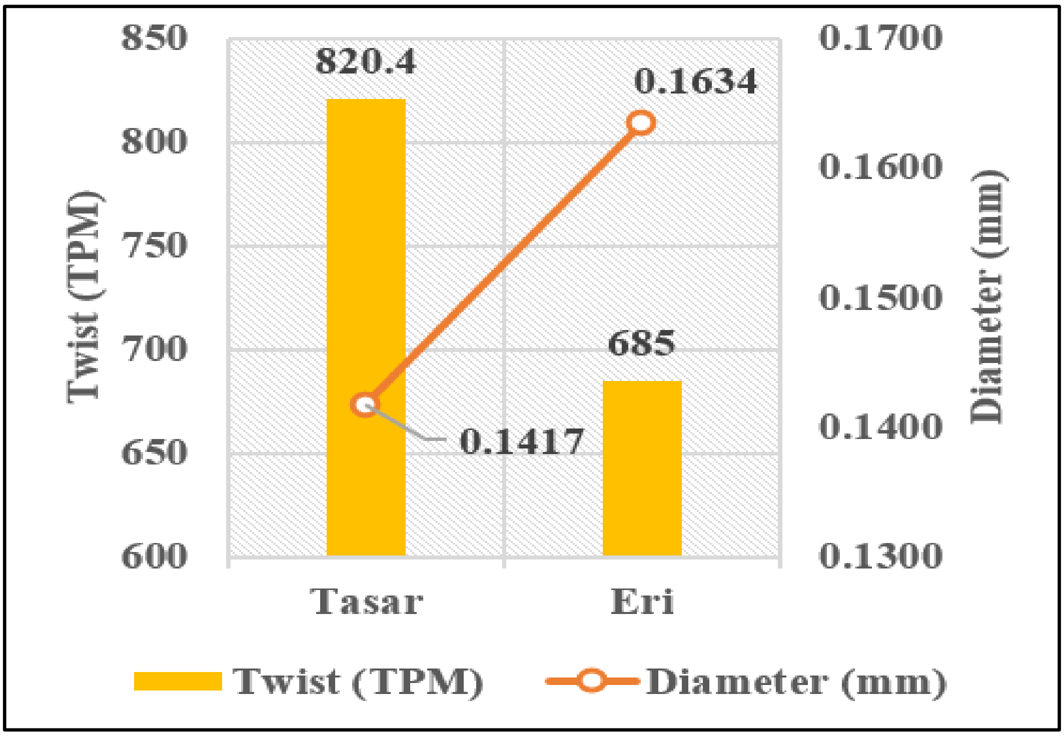

Fig 3 Twist Level and Yarn Diameter

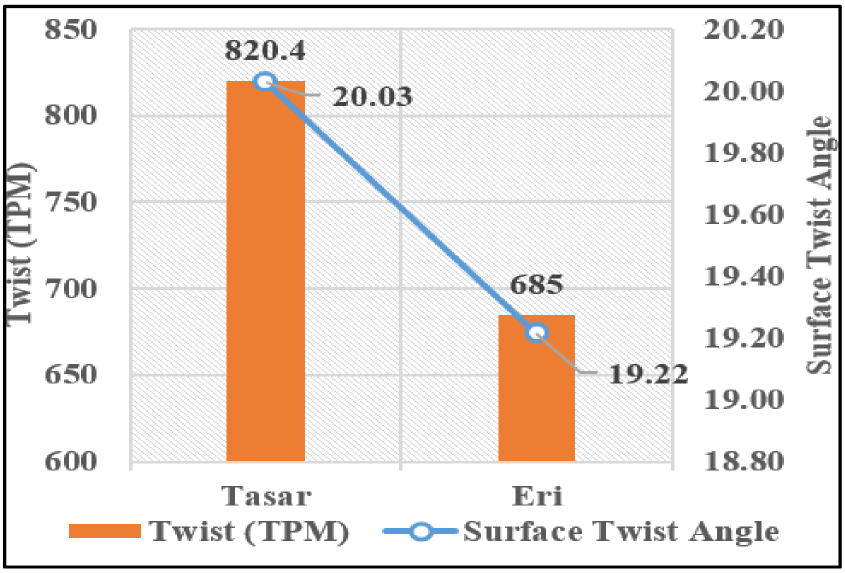

Fig 4 Twist Level and Surface Twist Angle

B. Determination of Tensile Properties:

Table 2 provided a comparative analysis of yarn strength characteristics—namely, Count Strength Product (CSP), single yarn tenacity (g/denier), and single yarn elongation (%)—for Tasar and Eri spun silk yarns.

➢ *Count Strength Product (CSP):*

The mean CSP was significantly higher for Eri yarns (3513.92 Ne·lbs) compared to Tasar yarns (1441.34 Ne·lbs), indicating that Eri yarns demonstrated more than twice the strength of Tasar yarns under standard testing conditions. The standard deviation (SD) was also higher in Eri (156.14) than Tasar (62.42), which reflected a broader spread of values in Eri samples, yet the coefficient of variation (CV%) remained similar—4.44% for Eri and 4.33% for Tasar—suggesting that both yarn types exhibited comparable consistency in terms of CSP.

➢ *Single Yarn Tenacity:*

In terms of tenacity, a more pronounced difference was observed. Eri yarns recorded a substantially higher mean tenacity of 1.56 g/den, whereas Tasar yarns showed a much lower mean value of 0.54 g/den. This highlighted the superior tensile strength of Eri yarns. Moreover, the CV% for Tasar yarn tenacity was significantly high at 34.76%, indicating a wide variability among the samples, which could be attributed to factors such as irregularity in fiber fineness, cohesion, or spinning parameters. In contrast, Eri yarns showed more uniformity in tenacity with a CV% of 21.83%.

➢ *Single Yarn Elongation:*

The elongation at break further supported the superior mechanical performance of Eri yarns. The mean elongation for Eri yarns was 20.96%, notably higher than the 13.98% observed in Tasar yarns. The variability in elongation was again more pronounced in Tasar (CV% = 18.83%) than in Eri (CV% = 8.73%), indicating that Eri yarns not only exhibited better elongation Behaviour but also offered greater consistency in this parameter.

C. Statistical Evaluation: ANOVA Analysis of Structural and Tensile Parameters

A one-way ANOVA was conducted to assess the statistical significance of differences in structural and tensile parameters between Tasar and Eri spun silk yarns. The results revealed in Table 3, that most parameters varied significantly between the two fiber types. Yarn diameter exhibited a significant difference ($F = 8.440$, $P = 0.006$), indicating that fiber type influenced the yarn thickness. Similarly, the linear density showed a statistically significant variation ($F = 18.090$, $P = 0.000$), reflecting deviations in yarn count between Tasar and Eri. Twist per meter (TPM) showed a highly significant difference ($F = 48.698$, $P = 0.000$), suggesting that the fibers responded differently during twisting, likely due to inherent structural disparities.

In contrast, the surface twist angle did not exhibit a significant difference ($F = 0.952$, $P = 0.335$), indicating uniformity in this parameter across both yarn types. However, the contraction factor ($F = 11.294$, $P = 0.002$) and retraction factor ($F = 11.712$, $P = 0.002$) both showed significant differences, implying that Tasar and Eri yarns responded differently to dimensional stress and recovery, likely due to variations in their physical and molecular structure. The Count Strength Product (CSP) also showed a highly significant variation ($F = 3038.401$, $P = 0.000$), reflecting a major difference in the combined strength and fineness of the yarns. Furthermore, single yarn tenacity ($F = 138.305$, $P = 0.000$) and elongation percentage ($F = 94.800$, $P = 0.000$) both differed significantly, indicating that Eri yarns had greater tensile strength and extensibility compared to Tasar yarns.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25jul1109

Table 2 Assessment of Tensile Properties

#	CSP (Ne. lbs)		Single Yarn Tenacity (gm/den)		Single Yarn Elongation (%)	
	Tasar	***Eri***	***Tasar***	***Eri***	***Tasar***	***Eri***
1	1358.69	3322.08	0.43	1.85	16.21	23.27
2	1380.22	3446.11	0.43	1.59	16.92	18.88
3	1514.92	3596.92	0.31	1.65	16.11	22.11
4	1431.51	3477.33	0.31	1.52	14.28	21.45
5	1374.37	3434.96	0.19	1.19	12.33	19.23
6	1367.56	3272.93	0.80	1.46	16.32	21.06
7	1497.33	3547.71	0.62	1.52	10.86	22.33
8	1513.30	3656.34	0.56	1.65	11.61	22.94
9	1536.58	3575.96	0.68	1.39	15.20	20.32
10	1486.24	3287.10	0.68	1.85	12.86	23.26
11	1331.32	3641.20	0.74	2.25	15.54	21.08
12	1527.32	3610.21	0.43	1.46	11.47	19.62
13	1494.88	3860.71	0.74	1.72	16.75	23.91
14	1415.81	3343.68	0.86	1.46	15.33	22.46
15	1390.96	3337.32	0.56	2.05	19.58	19.94
16	1397.46	3509.22	0.56	1.59	12.01	17.13
17	1444.45	3745.70	0.56	1.79	10.08	18.81
18	1435.63	3615.88	0.31	0.60	12.26	19.91
19	1469.61	3530.34	0.37	1.46	10.05	22.03
20	1458.77	3466.74	0.68	1.26	13.75	19.37
Mean	1441.34	3513.92	0.54	1.56	13.98	20.96
Std Dev	62.42	156.14	0.19	0.34	2.63	1.83
CV %	4.33	4.44	34.76	21.83	18.83	8.73
Min	1331.32	3272.93	0.19	0.60	10.05	17.13
Max	1536.58	3860.71	0.86	2.25	19.58	23.91

D. Correlation Among Structural and Tensile Properties:

The correlation analysis presented in Table 4 revealed significant relationships between various structural and tensile parameters of the spun silk yarns. Yarn diameter showed a moderate positive correlation with surface twist angle (r = 0.686), suggesting that thicker yarns tended to exhibit higher surface twist angles. Additionally, yarn diameter exhibited a weak positive correlation with linear density (r = 0.261), CSP (r = 0.404), single yarn tenacity (r = 0.363), and elongation (r = 0.428), indicating that increased yarn thickness was generally associated with improved tensile characteristics. Linear density was found to be moderately positively correlated with CSP (r = 0.595), tenacity (r = 0.522), and elongation (r = 0.425). These results implied that finer yarns (lower Nm values) were associated with better tensile strength and elongation properties, underscoring the importance of linear density control in yarn performance. Twist per meter (TPM) exhibited negative correlations with nearly all tensile properties, particularly with CSP (r = -0.745), single yarn tenacity (r = -0.595), and elongation (r = -0.626). This indicated that an increase in twist level adversely affected yarn strength and extensibility, possibly due to excessive fiber stress or reduced fiber alignment. Surface twist angle showed a moderate positive correlation with yarn diameter (r = 0.686), while its relationship with other parameters remained weak. This suggested that surface twist angle alone might not strongly influence yarn performance unless considered alongside other structural factors. Contraction factor and retraction factor were highly positively correlated with each other (r = 1.000), reflecting their similar nature in indicating yarn dimensional response. Both factors demonstrated moderate negative correlations with tensile parameters like CSP, tenacity, and elongation (ranging from -0.446 to -0.485), implying that higher contraction and retraction were detrimental to yarn strength and elasticity. The most notable findings were the very strong positive correlations between CSP and both single yarn tenacity (r = 0.879) and elongation (r = 0.833), confirming that these tensile traits contributed significantly to overall yarn performance. Additionally, single yarn tenacity also had a strong correlation with elongation (r = 0.806), emphasizing their interconnected nature in defining yarn quality.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25jul1109

Table 3 ANOVA Analysis of Structural and Tensile Parameters

Parameter	Source of Variation	SS	df	MS	F	P-value	F crit
Diameter (mm)	Between Groups	0.005	1	0.00	8.440	0.006	4.098
	Within Groups	0.021	38	0.00			
Linear Density (Nm)	Between Groups	26.598	1	26.60	18.090	0.000	4.098
	Within Groups	55.871	38	1.47			
Twist (TPM)	Between Groups	183331.600	1	183331.60	48.698	0.000	4.098
	Within Groups	143056.800	38	3764.65			
Surface Twist Angle	Between Groups	6.596	1	6.60	0.952	0.335	4.098
	Within Groups	263.216	38	6.93			
Contraction Factor	Between Groups	0.005	1	0.00	11.294	0.002	4.098
	Within Groups	0.016	38	0.00			
Retraction Factor	Between Groups	0.004	1	0.00	11.712	0.002	4.098
	Within Groups	0.013	38	0.00			
CSB (Ne. lbs)	Between Groups	42955802.121	1	42955802.12	3038.401	0.000	4.098
	Within Groups	537230.101	38	14137.63			
Single Yarn Tenacity (gm/den)	Between Groups	10.491	1	10.49	138.305	0.000	4.098
	Within Groups	2.882	38	0.08			
Single Yarn Elongation %	Between Groups	487.148	1	487.15	94.800	0.000	4.098
	Within Groups	195.271	38	5.14			

Table 4 Correlation of Structural and Tensile Parameters

	Diameter (mm)	Linear density (Nm)	Twist (TPM)	Surface Twist Angle	Contraction Factor	Retraction Factor	CSP(Ne.lbs)	Single Yarn Tenacity (gm/den)	Single Yarn Elongation (%)
Diameter (mm)	1								
Linear density (Nm)	0.261	1							
Twist (TPM)	-0.447	-0.404	1						
Surface Twist Angle	0.686	-0.044	0.340	1					
Contraction Factor	-0.408	-0.315	0.262	-0.205	1				
Retraction Factor	-0.417	-0.325	0.270	-0.207	1.000	1			
CSP (Ne. lbs)	0.404	0.595	-0.745	-0.173	-0.478	-0.485	1		
Single Yarn Tenacity (gm/den)	0.363	0.522	-0.595	-0.096	-0.460	-0.465	0.879	1	
Single Yarn Elongation (%)	0.428	0.425	-0.626	-0.055	-0.446	-0.452	0.833	0.806	1

IV. CONCLUSION

This study comprehensively examined the structural and tensile properties of Tasar and Eri spun silk yarns, offering detailed insights into their performance characteristics and interrelationships. Through systematic analysis, notable differences were observed in the yarn Behaviour attributed to the inherent properties of the two silk types and the spinning parameters employed.

The structural analysis revealed that while both yarn types were targeted at a nominal count of 60 Nm, Eri yarns exhibited closer conformity to this specification with lower variability, indicating more uniform yarn formation. Higher twist per meter in Tasar yarns led to reduced yarn diameter, suggesting greater fiber consolidation and compactness. Correspondingly, Tasar yarns also displayed a higher surface twist angle, although with increased variability, especially in Eri yarns, implying less consistent fiber alignment.

In terms of dimensional stability, Tasar yarns showed slightly higher contraction and retraction factors, likely due to the greater torsional stress introduced during spinning. However, both yarn types maintained relatively consistent contraction Behaviour, while retraction displayed considerable variability—more pronounced in Eri yarns—pointing to differences in fiber response post-spinning.

Tensile analysis highlighted the superior mechanical performance of Eri yarns. These yarns significantly outperformed Tasar in all tensile parameters, including count strength product (CSP), tenacity, and elongation, with lower coefficients of variation, indicating better overall strength, extensibility, and consistency. The substantial gap in tensile properties underlined the influence of fiber morphology and processing efficiency.

Statistical validation through ANOVA confirmed significant differences between the two yarn types in most structural and tensile parameters, reinforcing the distinct Behaviour of Tasar and Eri yarns under similar spinning conditions. Furthermore, correlation analysis revealed critical relationships: twist per meter negatively affected tensile properties, while CSP, tenacity, and elongation were strongly positively correlated with each other, establishing them as key indicators of yarn performance.

In conclusion, the findings of this study underscored the influence of fiber type and structural parameters—especially twist, linear density, and diameter—on the tensile Behaviour of spun silk yarns. Eri yarns, with superior strength and uniformity, emerged as more suitable for high-performance textile applications. These insights can guide optimization in yarn manufacturing and contribute to the development of silk products with enhanced mechanical quality and consistency.

ACKNOWLEDGEMENT

The experimental work presented in this study was carried out as part of an internship project undertaken by a student from Alagappa College of Technology, Anna University. The authors gratefully acknowledge the Central Silk Board, Ministry of Textiles, Government of India, for their financial assistance and for providing the essential research infrastructure that facilitated this work. Sincere thanks are also extended to the Director of the Central Silk Technological Research Institute (CSTRI) for his unwavering support, insightful guidance, and encouragement throughout the duration of the project. His dedication to promoting applied research in the silk industry played a pivotal role in the successful completion of this study.

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