**Impact of Hydrogen Peroxide Concentration during Cooking on the Physical Properties of Tasar Silk**

**ABSTRACT**

Tasar silk, a prominent variety of wild silk, is valued for its strength, luster, and eco-friendly attributes. However, the efficiency of cocoon processing and the quality of the resultant yarn are highly dependent on the cocoon cooking method. Traditional cooking practices often rely on alkaline agents, which can be environmentally harmful and may compromise fiber quality. In response, hydrogen peroxide (H₂O₂), a milder and eco-friendly oxidizing agent, was explored in this study to evaluate its effect on the cooking performance and tensile properties of Daba and Raily Tasar cocoons. The cocoons were cooked using a constant concentration of sodium carbonate and sodium silicate (4 g/L each), while the H₂O₂ concentration was varied at 5, 10, and 15 cc/L. The study revealed that Daba cocoons exhibited a decline in cooking efficiency and reeling yield with increasing peroxide concentration, alongside a rise in overcooked and burst cocoons—suggesting fiber degradation due to excessive oxidation. Conversely, Raily cocoons showed improved reeling performance and reduced hard cocoons with higher peroxide levels, indicating their requirement for stronger oxidative conditions. Linear density analysis showed no consistent pattern with H₂O₂ concentration, confirming that yarn thickness was primarily influenced by reeling operartions. Tensile testing indicated a decrease in tenacity and an increase in elongation with rising peroxide concentrations. ANOVA results confirmed that H₂O₂ concentration significantly affected tenacity and elongation in Daba yarns and elongation in Raily yarns, while tenacity in Raily yarns remained statistically unaffected. Overall, the findings emphasized the need for cocoon-specific optimization of oxidative treatment to balance reeling efficiency, yarn strength, and sustainability in Tasar silk processing.

**KEYWORDS**

Cooking & Reeling, Daba Tasar Cocoon, Hydrogen Peroxide, Linear Denisity, Raily Tasar Cocoon, Tensile Properties

# 1. INTRODUCTION

India remains the world’s only country producing all four major types of natural silk—Mulberry, Tasar, Muga, and Eri—with the non-mulberry varieties collectively known as Vanya silks. Among them, Tasar silk holds a prominent position due to its strength, coarse texture, distinctive natural luster, and eco-friendly production process. Unlike cultivated mulberry silk, Tasar is obtained from silkworms reared in forest-based ecosystems, lending it both ecological and economic importance. Tasar silk is harvested from two species: the temperate variant (*Antheraea proylei*), reared mainly in cooler Himalayan regions, and the tropical form (*Antheraea mylitta*), cultivated predominantly in the central and eastern states such as Jharkhand, Chhattisgarh, Odisha, and Bihar. Additional production exists in states like Maharashtra, Andhra Pradesh, and West Bengal [1-2].

Antheraea mylitta, the tropical Tasar silkworm, exhibits a wide range of regional adaptations and has given rise to several genetically distinct eco-races. Among these, Daba and Raily are the most economically viable and widely reared, owing to their reeling compatibility and filament quality. The Daba variant is more common and readily available, while Raily is prized for its coarse filament and superior sheen. Both eco-races play a significant role in supporting tribal communities, especially in forested regions, where Tasar sericulture forms an integral part of rural livelihoods. Hence, improving post-cocoon processing methods such as reeling and cooking can have a meaningful impact on both silk quality and socio-economic development [3].

A key stage in silk processing is cocoon cooking, which prepares the cocoon for reeling by softening or partially removing the sericin layer—a gummy protein that binds the silk filaments. The objective is to achieve uniform softening of the shell so that the silk thread can be smoothly unwound with minimal breaks. In Mulberry silk, this is achieved using boiling water due to the solubility of sericin; however, Tasar cocoons present a greater challenge. Their dense structure and the presence of insoluble compounds like tannins and calcium oxalate make their sericin more resistant to breakdown. Therefore, chemical treatments are essential to ensure proper softening and to enable efficient reeling [4].

Traditionally, Tasar cocoons are cooked in alkaline media such as soap and soda solutions. While these treatments are effective in softening sericin, they often carry drawbacks such as fiber weakening, uneven softening due to chemical residues. In light of growing environmental concerns and the need for sustainable practices, hydrogen peroxide (H2O2) has emerged as an alternative cooking agent. It is a mild oxidizing compound that decomposes into water and oxygen, making it safer for both fibers and the environment. Hydrogen peroxide effectively breaks down sericin but must be used in carefully controlled concentrations to avoid damaging the silk fibroin.The concentration of hydrogen peroxide used during the cooking process is a critical factor. Low concentrations may result in incomplete sericin removal and poor reelability, while higher concentrations can lead to oxidation of the fibroin, reducing fiber strength and elongation. Thus, striking a balance between effective sericin softening and preservation of silk’s mechanical properties is vital [5].

This study is designed to explore the effect of varying hydrogen peroxide concentrations during cocoon cooking on the physical and mechanical properties of Tasar silk filaments, specifically from Daba and Raily eco-races. The parameters examined include tenacity, elongation, filament fineness, which are crucial indicators of silk quality. The findings aim to contribute to the development of optimized, eco-friendly cooking protocols that enhance the reelability and performance characteristics of Tasar silk, ultimately supporting value addition and sustainable practices in India’s Vanya silk sector [6].

Traditionally, Tasar cocoon cooking is carried out using alkaline media comprising soap and soda, which aid in the softening and partial removal of sericin—the hydrophilic, glue-like protein that envelops the silk fibroin filament. These agents act by swelling the sericin layer, thereby facilitating its loosening and enabling the smooth unwinding of filaments during reeling. While this method has been widely practiced, it often results in non-uniform softening, particularly in compact and mineral-rich Tasar cocoons. Variations in cocoon shell structure, shell compactness, and internal composition—such as the presence of tannins and calcium oxalate—further complicate penetration and reaction uniformity. Moreover, excessive or prolonged exposure to alkaline conditions may compromise fibroin integrity, leading to a decline in filament strength, elongation, and overall reeling efficiency [7].

To address these limitations and improve process efficiency, hydrogen peroxide (H2O2), in combination with soda, has been explored as an alternative or supplementary cooking medium. Hydrogen peroxide functions as a mild oxidizing agent that enhances sericin breakdown, potentially leading to better filament release, cleaner filament surface, and improved uniformity in softening across the cocoon shell. However, the concentration of hydrogen peroxide plays a crucial role in determining its effectiveness. When used in sub-optimal concentrations, it may lead to inadequate sericin removal, resulting in filament entanglement and increased breakage during reeling. On the other hand, higher concentrations—especially when combined with soda—can accelerate oxidation reactions that may degrade the silk fibroin, adversely affecting mechanical properties such as tenacity and elongation. Therefore, it becomes imperative to optimize the peroxide-to-soda ratio to strike a balance between efficient sericin removal and the preservation of filament quality [8].

The present study investigates the impact of varying concentrations of hydrogen peroxide in the presence of soda during the cocoon cooking process on the physical and mechanical properties of Tasar silk filaments, specifically from the Daba and Raily eco-races, which are among the most commercially significant in India. The study focuses on evaluating critical performance parameters such as tenacity, elongation, and filament fineness, which are indicative of both reeling performance and raw silk quality. The findings are expected to aid in establishing optimized cooking protocols for enhanced cocoon processing, improved filament yield, and superior quality silk production in the Tasar sector [9].

# 2. EXPERIMENTAL

**2.1 Materials**

Stifled Daba and Raily Tasar cocoons were procured from the Raw Material Bank (RMB), Chaibasa, Jharkhand and used as the primary raw material for this study. Additionally, chemicals such as sodium carbonate (Na2CO3), hydrogen peroxide (H2O2), and sodium silicate (Na2SiO3) were procured and utilized in the cocoon cooking processes.

**2.2 Assessment of Cocoon Characteristics**

A comprehensive assessment of cocoon characteristics was conducted for two commonly reared Tasar silk eco-races—Daba and Raily—to determine their suitability for reeling and further processing. The findings from the assessment are presented in Table 1.

**Table 1: Cocoon Characteristics**

|  |  |  |
| --- | --- | --- |
| **Eco-race** | **Daba** | **Raily** |
| Single Cocoon Weight (g) | 12–14 | 15–18 |
| Single Shell Weight (g) | 1.45–2.00 | 2.50–3.00 |
| Filament Denier (d) | 10 | 10 |
| Shell Ratio (%) | 12–14 | 16–17 |
| Average Filament Length (m) | 850–1200 | ~1400 |
| Shell Length (cm) | 4.82 | 5.24 |
| Shell Width (cm) | 2.96 | 3.65 |
| Shell Thickness (mm) | 0.34 | 0.92 |
| Peduncle Length (cm) | 6.5 | 3.4 |

**2.3 Cooking & Reeling Process**

In the context of Tasar silk processing, the permeation cooking method demonstrated significantly higher effectiveness in terms of silk recovery and cooking efficiency compared to the conventional open pan approach. This improvement was primarily attributed to enhanced moisture penetration and more uniform softening of the sericin layer, which facilitated smoother filament extraction and increased silk yield.The process began with the placement of stifled Tasar cocoons into a vacuum permeation chamber, where they were subjected to three treatment cycles under a vacuum pressure of 300 mm Hg. Each cycle lasted between 5 to 7 minutes, ensuring adequate infusion of moisture into the cocoon shell structure. Following permeation, the cocoons were boiled in plain water for 20 to 25 minutes at temperatures ranging from 95°C to 97°C, allowing for optimal sericin softening. To minimize filament breakage and maintain cocoon integrity, a Two-Pan Cooking Machine was used to gradually cool the cocoons post boiling.After cooling, the cocoons were transferred into a chemical bath maintained at 60°C to 70°C and soaked overnight. This bath contained varying concentrations of hydrogen peroxide (H2O2) and other cooking agents. The detailed composition and preparation of the chemical solutions used in the experimental trials are presented in Table 2 [10-12].

**Table 2: Details of Chemical Solutions in Cooking Process**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Sample Code** | **Type** | **Cooking Chemicals Used** | | |
| **Na2CO3 (gm/l)** | **NaSiO3 (gm/l)** | **H2O2 (cc/l)** |
| D1 | Daba | 4 | 4 | 5 |
| D2 | Daba | 4 | 4 | 10 |
| D3 | Daba | 4 | 4 | 15 |
| R1 | Raily | 4 | 4 | 5 |
| R2 | Raily | 4 | 4 | 10 |
| R3 | Raily | 4 | 4 | 15 |

The reeling trials were subsequently carried out using the Tasar Buniyaad Reeling Machine, for efficient extraction of Tasar silk filaments. Following the initial reeling process, the silk was subjected to re-reeling, which involved transferring the reeled yarn onto standardized reels to improve package formation, enhance evenness, and eliminate filament entanglements or neps.

**2.4 Analysis the Cooking and Reeling Performances**

To evaluate the effectiveness of cocoon softening following treatment with varying concentrations of hydrogen peroxide (H₂O₂), Cooking Efficiency was calculated using the following formula (1):

..........(1)

In addition to cooking efficiency, the overall reeling performance was assessed using the following key parameters [13]:

**Raw Silk Recovery (%):** This measures the actual amount of silk obtained relative to the cocoon shell weight, excluding natural and process-related losses. It was calculated using formula (2):

..........(2)

**Silk Waste (%): Representing the proportion of unrecoverable silk material lost during reeling, this parameter was determined using formula (4):**

..........(3)

**2.5 Testing Methods**

The linear density and tensile properties of Daba and Raily Tasar silk yarns, obtained from various trials involving different concentrations of hydrogen peroxide (H2O2), were evaluated in accordance with IS 17618:2021 standards. Linear density was determined using a wrap reel in combination with a precision analytical balance, while tenacity and elongation were measured using a Serigraph tensile testing apparatus.

# 3. RESULTS AND DISCUSSION

**3.1 Effect of Hydrogen Peroxide Concentration on Tasar Cocoon Cooking Performance**

**Table 3: Tasar Cocoon Cooking Performance**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Parameters** | **D1** | **D2** | **D3** | **R1** | **R2** | **R3** |
| Nos of Total Cocoons | 40 | 40 | 40 | 30 | 30 | 30 |
| Nos of Reelable Cocoons | 32 | 27 | 24 | 7 | 12 | 16 |
| Nos of Overcooked/ Burst Cocoons | 4 | 9 | 12 | 0 | 0 | 0 |
| Nos of Hard Cocoons | 4 | 4 | 4 | 23 | 18 | 14 |
| Cooking Efficiency % | 80.0 | 67.5 | 60.0 | 23.3 | 40.0 | 53.3 |

**Figure 1: Trial Wise Tasar Cocoon Cooking Performance**

The effect of varying hydrogen peroxide (H₂O₂) concentrations during the cocoon cooking process was systematically investigated to evaluate its impact on the cooking performance of Daba and Raily Tasar cocoons. The trials were conducted using fixed concentrations of sodium carbonate (Na₂CO₃) and sodium silicate (Na₂SiO₃) at 4 gm/l each, while H₂O₂ was varied at 5, 10, and 15 cc/l. The results, as presented in Table 3, clearly demonstrate that the response to peroxide treatment varied significantly between the two cocoon types, owing to their inherent structural and compositional differences.

As illustrated in Figure 1, the Daba cocoon samples (D1–D3) exhibited a decreasing trend in the number of reelable cocoons with increasing H₂O₂ concentration—from 32 (80%) in D1 to 24 (60%) in D3. Concurrently, the number of overcooked or burst cocoons increased sharply, from 4 to 12, indicating that higher peroxide concentrations led to excessive degradation of the sericin layer and possible hydrolytic weakening of the cocoon shell. This degradation likely compromised filament integrity during the cooking process. Interestingly, the number of hard cocoons remained constant at 4 across all Daba trials, suggesting that higher peroxide levels primarily caused over-softening rather than insufficient softening in this variety.

In contrast, Raily cocoon samples (R1–R3) responded positively to increased H₂O₂ concentrations. The number of reelable cocoons increased from 7 (23.3%) in R1 to 16 (53.3%) in R3, while the number of hard cocoons decreased significantly from 23 to 14. Notably, no overcooked or burst cocoons were observed in any of the Raily trials, indicating that the structurally tougher and more compact Raily cocoons benefited from the stronger oxidative action of higher peroxide levels, which facilitated better sericin solubilization and uniform softening. The corresponding improvement in cooking efficiency—from 23.3% to 53.3%—further corroborated this trend.

**3.2 Evaluation of Reeling Performances**

**Table 4: Tasar Cocoon Reeling Performance**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Parameters** | | **D1** | **D2** | **D3** | **R1** | **R2** | **R3** |
| Waste generated (gm) | Defloss | 12.12 | 8.85 | 10.79 | 12.62 | 12.73 | 14.99 |
| Reeled | 1.93 | 2.88 | 2.39 | 0.89 | 1.95 | 2.38 |
| Pelade | 2.60 | 3.78 | 6.17 | 0.45 | 1.12 | 1.83 |
| Raw Silk Recovery % | | 58 | 53 | 50 | 41 | 45 | 49 |
| Waste % | | 42 | 47 | 50 | 59 | 55 | 51 |

Table 4 presented the reeling performance of Daba and Raily Tasar cocoons treated with varying concentrations of hydrogen peroxide (H2O2), highlighting the influence of oxidative treatment on silk recovery and waste generation. In Daba samples (D1–D3), a gradual decline in raw silk recovery was observed with increasing H2O2 concentration, dropping from 58% in D1 to 50% in D3. This trend suggested that higher peroxide levels caused over-softening or partial degradation of the filament structure, leading to increased filament breakage during reeling. Correspondingly, the overall waste percentage rose from 42% to 50%, with a noticeable increase in pelade waste from 2.60 gm in D1 to 6.17 gm in D3. Reeled waste also fluctuated, peaking at 2.88 gm in D2. The amount of defloss waste, although variable, showed no clear correlation with peroxide concentration, indicating that defloss generation was more influenced by brushing efficiency and cocoon surface characteristics rather than chemical treatment.

In contrast, Raily cocoons (R1–R3) responded positively to increased H2O2 levels, with raw silk recovery improving from 41% in R1 to 49% in R3. This enhancement was attributed to better sericin removal and uniform softening, which facilitated improved filament extraction during reeling. Simultaneously, the waste percentage decreased from 59% to 51%, indicating a more efficient utilization of cocoon material. Although pelade waste increased slightly, from 0.45 gm in R1 to 1.83 gm in R3, it was accompanied by higher silk yield, suggesting that a greater portion of the filament was successfully reeled. The increase in reeled waste from 0.89 gm to 2.38 gm across R1 to R3 also supported improved reeling activity. These findings reinforced that Daba cocoons performed optimally at lower peroxide concentrations to maintain filament integrity and reduce reeling losses, whereas Raily cocoons benefited from higher oxidative strength, which enhanced reeling performance and reduced total waste.

**3.3 Assessment of Linear Density**

**Table 5: Assessment of Linear Density**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **#** | **D1** | **D2** | **D2** | **R1** | **R2** | **R3** |
| 1 | 74.66 | 56.76 | 65.36 | 71.44 | 68.16 | 70.60 |
| 2 | 80.22 | 56.76 | 73.96 | 69.50 | 70.94 | 82.58 |
| 3 | 71.00 | 58.98 | 65.70 | 67.38 | 62.78 | 69.52 |
| 4 | 73.30 | 58.24 | 64.12 | 67.56 | 70.52 | 70.80 |
| 5 | 59.28 | 59.80 | 62.56 | 69.44 | 68.24 | 70.82 |
| 6 | 75.98 | 56.98 | 71.48 | 62.14 | 65.12 | 84.78 |
| 7 | 60.06 | 55.26 | 61.04 | 76.04 | 68.16 | 77.42 |
| 8 | 60.80 | 58.08 | 64.24 | 64.96 | 62.96 | 79.14 |
| 9 | 73.02 | 66.26 | 68.12 | 64.08 | 66.00 | 78.62 |
| 10 | 69.62 | 65.70 | 65.24 | 76.76 | 64.18 | 72.48 |
| 11 | 66.24 | 56.26 | 57.26 | 62.76 | 62.74 | 71.72 |
| 12 | 70.46 | 55.94 | 57.66 | 74.20 | 66.76 | 71.54 |
| 13 | 80.08 | 65.86 | 65.88 | 77.24 | 70.18 | 77.74 |
| 14 | 82.24 | 66.36 | 64.54 | 75.82 | 66.02 | 71.30 |
| 15 | 70.50 | 58.60 | 61.62 | 67.64 | 75.56 | 73.64 |
| 16 | 72.42 | 66.48 | 71.56 | 66.64 | 69.10 | 68.62 |
| 17 | 64.28 | 67.90 | 61.62 | 73.66 | 65.52 | 81.08 |
| 18 | 68.24 | 57.36 | 70.50 | 63.74 | 73.96 | 81.20 |
| 19 | 60.50 | 55.26 | 64.94 | 74.60 | 75.48 | 69.26 |
| 20 | 67.34 | 66.58 | 66.24 | 68.80 | 67.92 | 69.46 |
| Mean | 70.01 | 60.47 | 65.18 | 69.72 | 68.02 | 74.62 |
| Std Dev | 6.831 | 4.657 | 4.398 | 4.956 | 3.897 | 5.143 |
| CV % | 9.76 | 7.70 | 6.75 | 7.11 | 5.73 | 6.89 |
| MIN | 59.28 | 55.26 | 57.26 | 62.14 | 62.74 | 68.62 |
| MAX | 82.24 | 67.90 | 73.96 | 77.24 | 75.56 | 84.78 |

Table 5 presented the linear density assessment of Tasar silk yarns reeled from Daba and Raily cocoons treated with varying concentrations of hydrogen peroxide (H2O2). The mean denier for Daba samples ranged from 60.47 to 70.01, while for Raily samples, it varied from 68.02 to 74.62. Despite the differences in H2O2 concentrations, no consistent trend was observed, indicating that linear density was not significantly influenced by the chemical treatment. Instead, variations in yarn thickness were primarily attributed to reeling-related factors such as machine settings, tension, filament uptake speed, and operator handling. The coefficient of variation (CV%) ranged from 5.73% to 9.76%, with relatively better uniformity observed in Raily samples, possibly due to smoother reeling facilitated by improved cocoon softening. The denier values across all samples remained within acceptable ranges for Tasar silk, with minimum and maximum values reflecting occasional inconsistencies during reeling. Overall, the results confirmed that linear density was governed more by reeling parameters than by the oxidative treatment used in cocoon cooking, underscoring the importance of controlled reeling conditions for producing uniform Tasar yarn.

**3.4 Influence of Hydrogen Peroxide Concentration on Tensile Properties of Tasar Silk Yarns**

**Table 6: Assessment of Tensile Properties**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **#** | **D1** | | **D2** | | **D3** | | **R1** | | **R2** | | **R3** | |
| **T** | **E** | **T** | **E** | **T** | **E** | **T** | **E** | **T** | **E** | **T** | **E** |
| 1 | 2.43 | 28 | 2.20 | 28 | 2.26 | 29 | 1.92 | 31 | 2.20 | 27 | 2.26 | 30 |
| 2 | 2.24 | 31 | 2.20 | 28 | 1.77 | 32 | 2.36 | 25 | 2.08 | 29 | 1.77 | 34 |
| 3 | 2.06 | 30 | 2.33 | 30 | 2.26 | 33 | 2.36 | 26 | 2.07 | 25 | 2.26 | 28 |
| 4 | 3.36 | 32 | 2.32 | 29 | 2.26 | 31 | 1.77 | 34 | 2.09 | 28 | 2.26 | 32 |
| 5 | 2.43 | 27 | 2.30 | 30 | 2.74 | 30 | 1.62 | 29 | 1.69 | 33 | 2.74 | 35 |
| 6 | 3.55 | 23 | 2.19 | 28 | 2.09 | 32 | 2.06 | 30 | 2.07 | 32 | 2.09 | 29 |
| 7 | 3.18 | 30 | 2.17 | 27 | 1.13 | 32 | 2.51 | 30 | 2.20 | 28 | 1.93 | 30 |
| 8 | 2.24 | 25 | 2.37 | 30 | 1.45 | 29 | 1.92 | 27 | 1.96 | 32 | 1.85 | 28 |
| 9 | 2.17 | 27 | 2.11 | 26 | 2.09 | 31 | 1.92 | 32 | 2.08 | 26 | 2.09 | 31 |
| 10 | 2.62 | 25 | 1.86 | 34 | 1.45 | 32 | 2.21 | 28 | 2.10 | 25 | 1.45 | 31 |
| 11 | 2.62 | 26 | 2.13 | 28 | 1.77 | 29 | 2.65 | 26 | 2.07 | 28 | 1.90 | 31 |
| 12 | 2.24 | 27 | 2.15 | 27 | 1.94 | 28 | 2.06 | 30 | 2.06 | 27 | 1.94 | 33 |
| 13 | 2.22 | 24 | 1.86 | 33 | 1.77 | 30 | 2.06 | 31 | 2.14 | 28 | 1.77 | 34 |
| 14 | 1.87 | 30 | 2.11 | 27 | 2.58 | 29 | 2.06 | 28 | 1.89 | 33 | 2.58 | 34 |
| 15 | 1.68 | 31 | 2.22 | 30 | 1.45 | 31 | 1.62 | 31 | 2.12 | 30 | 1.45 | 33 |
| 16 | 2.62 | 26 | 1.99 | 32 | 1.93 | 30 | 2.21 | 28 | 2.10 | 28 | 1.93 | 36 |
| 17 | 1.68 | 30 | 1.95 | 34 | 1.72 | 33 | 1.77 | 31 | 1.96 | 35 | 1.92 | 33 |
| 18 | 2.80 | 24 | 2.40 | 28 | 2.09 | 33 | 2.65 | 25 | 2.13 | 29 | 2.09 | 32 |
| 19 | 1.49 | 29 | 2.17 | 27 | 1.45 | 36 | 2.06 | 28 | 2.12 | 30 | 1.45 | 30 |
| 20 | 2.06 | 27 | 2.10 | 26 | 2.42 | 28 | 2.21 | 29 | 2.06 | 34 | 2.42 | 32 |
| Mean | 2.38 | 27.60 | 2.16 | 29.10 | 1.93 | 30.90 | 2.10 | 28.95 | 2.06 | 29.35 | 2.01 | 31.80 |
| Std Dev | 0.55 | 2.66 | 0.15 | 2.49 | 0.42 | 2.02 | 0.12 | 2.35 | 0.10 | 1.89 | 0.11 | 1.59 |
| CV % | 23.00 | 9.65 | 7.05 | 8.56 | 21.89 | 6.55 | 5.66 | 6.80 | 4.89 | 7.10 | 5.57 | 4.06 |
| MIN | 1.49 | 23.00 | 1.86 | 26.00 | 1.13 | 28.00 | 1.62 | 25.00 | 1.69 | 25.00 | 1.45 | 28.00 |
| MAX | 3.55 | 32.00 | 2.40 | 34.00 | 2.74 | 36.00 | 2.65 | 34.00 | 2.20 | 35.00 | 2.74 | 36.00 |

T= Tenacity (gm/den), E= Breaking Elongation%

Table 6 presented the tensile properties of Tasar silk yarns reeled from Daba and Raily cocoons treated with varying concentrations of hydrogen peroxide (H₂O₂), focusing on tenacity (gm/den) and elongation at break (%). Each sample set comprised 20 observations, and statistical parameters such as mean, standard deviation, coefficient of variation (CV%), and range were calculated to analyze the effects of oxidative treatment on yarn strength and flexibility. Tenacity was a critical indicator of filament strength and spinning performance. Among the Daba samples, D1 (5 cc/l H₂O₂) showed the highest average tenacity (2.38 gm/den), followed by D2 (2.16 gm/den) and D3 (1.93 gm/den). This gradual reduction suggested that increasing peroxide concentrations during cocoon cooking led to fiber weakening due to oxidative degradation, particularly affecting the sericin-cemented fiber bundle integrity. A similar pattern was observed in the Raily series: R1 had a slightly higher mean tenacity (2.10 gm/den) compared to R2 (2.06 gm/den) and R3 (2.01 gm/den). Although the decline was not as pronounced as in Daba, it still implied that excessive peroxide concentrations (15 cc/l) induced mild fiber embrittlement, especially with prolonged cooking durations. The standard deviation and CV% were higher in Daba samples (up to 23.0% in D1), indicating greater variability in fiber strength, which was potentially caused by inconsistent softening or reeling tension. In contrast, the Raily samples displayed tighter control over tenacity variation (CV as low as 4.89% in R2), possibly due to better alignment and reeling stability in harder cocoons treated with higher peroxide concentrations. Breaking elongation reflected the flexibility and ductility of silk fibers. Elongation increased with rising H₂O₂ concentrations across both cocoon types. In Daba yarns, elongation rose from 27.6% (D1) to 30.9% (D3), and in Raily yarns, from 28.95% (R1) to 31.80% (R3). This indicated that mild oxidation facilitated partial removal or plasticization of sericin, which increased the extensibility of fibroin filaments. It also pointed to a softening effect on the crystalline and amorphous regions of silk fibers, improving their capacity to elongate before breakage. Notably, the lowest CV% in elongation (4.06% in R3) indicated uniform softening and mechanical behavior at higher peroxide concentrations in Raily cocoons.

Table 7 presented the results of ANOVA analysis performed to evaluate the statistical significance of the effect of hydrogen peroxide (H₂O₂) concentration on the tensile properties—tenacity and breaking elongation (%)—of Daba and Raily Tasar silk yarns. For Daba Tasar silk yarns, the ANOVA results for tenacity showed a significant difference between groups treated with different H₂O₂ concentrations. The F-value was 5.957, which exceeded the critical F-value of 3.159, and the associated p-value was 0.004, indicating that the differences in mean tenacity across D1, D2, and D3 were statistically significant at the 95% confidence level. This confirmed that peroxide concentration had a notable impact on the tensile strength of Daba yarns, likely due to fiber weakening at higher oxidative levels. In contrast, for Raily Tasar silk yarns, the F-value for tenacity was only 0.562, with a p-value of 0.573, well above the 0.05 threshold. This indicated that the differences in tenacity among R1, R2, and R3 were not statistically significant. Hence, peroxide concentration did not significantly affect the strength of Raily yarns, suggesting greater resistance to oxidative degradation in this cocoon variety. Regarding breaking elongation, both Daba and Raily yarns exhibited statistically significant differences across peroxide treatments. For Daba yarns, the F-value was 9.419 with a p-value of 0.000, and for Raily yarns, the F-value was 7.322 with a p-value of 0.001—both exceeding the F-critical value of 3.159. These results confirmed that varying H₂O₂ concentrations significantly influenced the elongation properties of both cocoon types. The observed increase in elongation with rising peroxide concentration, as noted earlier, was thus statistically validated

**Table 7: ANOVA Analysis of Tensile Properties of Daba and Raily Tasar Silk Yarns**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | | **Source of Variation** | **SS** | **df** | **MS** | **F** | **P-value** | **F crit** |
| Tenacity (gm/den) | Daba Tasar Silk Yarn | Between Groups | 1.988 | 2 | 0.994 | 5.957 | 0.004 | 3.159 |
| Within Groups | 9.513 | 57 | 0.167 |
| Raily Tasar Silk Yarn | Between Groups | 0.085 | 2 | 0.043 | 0.562 | 0.573 | 3.159 |
| Within Groups | 4.323 | 57 | 0.076 |
| Breaking Elongation % | Daba Tasar Silk Yarn | Between Groups | 109.200 | 2 | 54.600 | 9.419 | 0.000 | 3.159 |
| Within Groups | 330.400 | 57 | 5.796 |
| Raily Tasar Silk Yarn | Between Groups | 95.233 | 2 | 47.617 | 7.322 | 0.001 | 3.159 |
| Within Groups | 370.700 | 57 | 6.504 |

**4. Conclusion**

In conclusion, the study highlights that the optimal concentration of H₂O₂ for cocoon cooking is cocoon-type specific. For Daba cocoons, lower peroxide concentrations (5 cc/l) were found to be optimal for preserving filament strength and maximizing reeling yield. In contrast, Raily cocoons required higher concentrations (up to or beyond 15 cc/l) to effectively address their higher sericin content and structural rigidity. These findings emphasize the need for cocoon-specific chemical protocols to enhance cooking efficiency, ensure better reeling performance, and improve overall raw silk quality in Tasar silk processing. The data revealed a trade-off between tenacity and elongation as H₂O₂ concentration increased. For Daba cocoons, lower peroxide levels (5 cc/l) preserved tensile strength, while higher levels increased ductility at the cost of strength. In Raily cocoons, a more balanced response was noted, with a modest decline in strength and a significant improvement in elongation, indicating that higher oxidative treatment (up to 15 cc/l) was more beneficial in softening without severely degrading fiber properties. Overall, the tensile behavior of Tasar silk yarns was influenced by both peroxide concentration and cocoon type, suggesting the need for process optimization to balance strength and extensibility in finished yarns depending on their end-use requirements. The ANOVA analysis demonstrated that tenacity in Daba yarns and elongation in both Daba and Raily yarns were significantly affected by the concentration of hydrogen peroxide used during cocoon cooking. However, tenacity in Raily yarns remained unaffected, reflecting their better oxidative tolerance and structural resilience. These findings underscored the importance of tailoring peroxide concentrations to cocoon type to achieve desired tensile performance in Tasar silk yarns.

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