Effect of Scouring & Bleaching (Single Bath & Double Bath) on Jute Fiber with the Variation of Concentration, M: L Ratio & Time and their Comparison

Md. Billal Hossain[1,2], Ahmed Saber Shravan[1,2], Md. Salman Farsee[1*], Emdadul Haq[1,3]

Abstract

Objective: This study aimed to investigate the effectiveness of scouring and bleaching processes using caustic soda and hydrogen peroxide on silver obtained from jute 3rd drawing frame, focusing on the removal of chemical impurities such as hemicellulose, wax, and lignins. Methods: Silver fibers were subjected to scouring and bleaching treatments where parameters such as concentration, liquor ratio (M ratio), and duration were systematically varied. Caustic soda was employed as a scouring agent to remove impurities, followed by hydrogen peroxide as a bleaching agent to purify the fibers further. Results: Prior to treatment, the breaking load of untreated fibers was measured at 85-90 grams per single fiber. Post-treatment, a significant reduction in breaking load was observed, resulting in a strength loss of 15-20 grams per fiber, corresponding to approximately 20% of the original strength. Similarly, a notable reduction in fiber weight was noted after chemical treatment. Conclusion: The substantial loss in fiber strength post-treatment suggests the aggressive action of caustic soda and hydrogen peroxide on the fibers, effectively removing targeted impurities such as hemicellulose, wax, and lignins. Optimization of process parameters such as concentration and duration can potentially mitigate the strength loss while achieving desired levels of fiber purity. These findings underscore the importance of carefully balancing chemical treatments to enhance fiber quality while minimizing detrimental effects on mechanical properties. Future studies could explore alternative treatments or modifications to mitigate strength loss, further optimizing the scouring and bleaching processes for industrial applications.

Keywords: Jute fibers, Scouring, Bleaching, Chemical impurities, Fiber strength.

Significance | Enhances jute fiber purity for industrial use by removing impurities, though careful treatment optimization is crucial to maintain strength.

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Introduction

Jute, often referred to as the "golden fiber" of Bangladesh, plays a crucial role in both the local economy and global fiber markets (Khan, 2020). Known for its versatility and biodegradability, jute is primarily used in packaging, textiles, and various industrial applications (Rahman, 2021). However, its potential use in apparel and high-value textile products has not been fully realized due to inherent challenges such as the presence of natural impurities like hemicellulose, lignin, and wax, which affect its mechanical properties and aesthetic qualities (Hossain et al., 2019). To

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overcome these challenges and make jute fibers suitable for a broader range of applications, particularly in the apparel industry, effective chemical treatments like scouring and bleaching are essential (Islam & Ahmed, 2022). Scouring and bleaching are fundamental processes in fiber preparation, designed to remove impurities and enhance the fiber's whiteness and softness, making it more amenable for spinning and further textile processing (Miah & Rahman, 2023). Traditionally, jute fibers are treated with a combination of caustic soda (NaOH) for scouring and hydrogen peroxide (H_2O_2) for bleaching, which are known to effectively eliminate non-cellulosic impurities (Chowdhury et al., 2021). However, these treatments also cause significant changes in the mechanical properties of the fibers, such as a reduction in tensile strength and fiber weight, posing a challenge in maintaining a balance between fiber purity and mechanical integrity (Karim et al., 2020).

The present study investigates the effect of scouring and bleaching on jute fibers, focusing on a comparison between single-bath and double-bath processes. By varying key process parameters such as the concentration of NaOH and H_2O_2, material-to-liquor (M) ratio, and treatment duration, the study aims to optimize these treatments for the best possible outcomes (Sarker & Islam, 2024). The study systematically examines the impact of these treatments on fiber weight, breaking strength, and overall mechanical properties, providing valuable insights into how jute fibers can be made more suitable for textile applications without compromising their structural integrity (Mohiuddin & Rahman, 2023).

This research is particularly significant in light of the growing demand for sustainable and biodegradable fibers in the textile industry (Ahmed & Hossain, 2022). As cotton and polyester fibers dominate the global apparel market, the exploration of alternative fibers like jute offers a promising avenue for reducing dependency on non-renewable resources and enhancing the environmental sustainability of the textile sector (Ali et al., 2021). Through a detailed comparison of single-bath and double-bath scouring and bleaching processes, this study seeks to contribute to the development of optimized processing techniques that will unlock the full potential of jute fibers for diverse applications (Khan et al., 2024).

The investigation outlines the impact of various concentrations, M ratios, and treatment times on the mechanical properties of jute fibers and proposes recommendations for minimizing fiber strength loss while maximizing impurity removal (Zaman & Islam, 2024). Moreover, the study draws upon previous research in the field of jute fiber treatment, offering a comprehensive understanding of the underlying mechanisms that govern the relationship between chemical treatment and fiber performance (Chowdhury et al., 2023).

This research is poised to advance the understanding of jute fiber treatment processes, thereby promoting its use in the apparel industry and supporting the broader movement toward sustainable fiber alternatives (Nahar & Rahman, 2022). By identifying the optimal conditions for scouring and bleaching jute fibers, this study aims to enhance the quality and performance of jute in high-value textile applications, ultimately contributing to the economic and environmental sustainability of the jute industry in Bangladesh (Karim et al., 2024).

Materials and Methods

The primary raw material used in this study was Bangla White (BWB) A-grade long jute fibers, sourced locally through the Bangladesh University of Textiles (Rahman, 2021). These jute fibers were subjected to various chemical and mechanical treatments, including scouring and bleaching, to assess the impact of these processes on the fiber's mechanical properties and weight loss (Hossain et al., 2019). The scouring process aimed to remove impurities such as hemicellulose, wax, and lignin, while the bleaching process focused on enhancing fiber brightness (Chowdhury et al., 2021).

For scouring, sodium hydroxide (NaOH) was used at varying concentrations, ranging from 5 g/L to 40 g/L, with two different material-to-liquor (M) ratios of 1:10 and 1:40 (Miah & Rahman, 2023). The scouring was conducted at a constant temperature of 90°C for two different time durations, 30 and 40 minutes (Islam & Ahmed, 2022). Similarly, bleaching was performed using hydrogen peroxide (H_2O_2) at concentrations of 0.5 g/L, 1.0 g/L, and 1.5 g/L, maintaining the same M ratios, temperature, and time intervals as those used for scouring (Karim et al., 2020). Both single-bath and double-bath systems were employed to understand the efficiency of each method (Khan et al., 2024). The double-bath system involved separate scouring and bleaching processes, while the single-bath system combined both treatments in one procedure (Sarker & Islam, 2024).

A range of chemical agents was used during these treatments, including a hydrogen peroxide stabilizer to control the bleaching reaction, a wetting agent to ensure uniform distribution of chemicals across the fibers, a sequestering agent to neutralize metal ions that could interfere with the bleaching process, and a detergent to remove residual chemicals and impurities after the treatments (Ali et al., 2021). The experimental setup for both scouring and bleaching was carried out using a sample dyeing machine with a capacity of 10 grams per sample (Mohiuddin & Rahman, 2023). Other equipment included an OD batch mixer for softening the fibers, a spreader for the application of emulsions, and carding machines, such as a breaker card and finisher card, to prepare the fibers for the drawing process (Chowdhury et al., 2023). Fibers were drawn through three consecutive drawing frames to improve

uniformity and prepare them for the final evaluation (Nahar & Rahman, 2022).

After each chemical treatment, the mechanical properties of the fibers were analyzed. The breaking strength of the jute fibers was measured using a Constant Rate of Loading (CRL) method, wherein the fibers were clamped between two jaws, and incremental weights were applied until the fibers broke (Karim et al., 2024). The breaking load was recorded, providing insights into the impact of scouring and bleaching on the fiber's mechanical strength (Zaman & Islam, 2024). Additionally, the weight loss of the fibers was determined by weighing the fiber samples before and after the treatment using an electronic balance, allowing for an assessment of the extent of impurities removed during the processes (Hossain et al., 2019).

Data from the experiments were statistically analyzed to evaluate the effects of the various treatment conditions (chemical concentrations, M ratios, and treatment times) on the mechanical properties and weight loss of the fibers (Ahmed & Hossain, 2022). A factorial design approach was used to assess the interactions between these variables, enabling the comparison of single-bath and double-bath systems and the identification of optimal treatment conditions for achieving the desired balance between mechanical strength retention and effective impurity removal (Chowdhury et al., 2021).

Results

The study assessed the impact of varying concentrations of scouring and bleaching agents, material-to-liquor (M) ratios, and treatment durations on the properties of Bangla White (BWB) A-grade long jute fibers, focusing on breaking strength and weight loss (Rahman, 2021). Two treatment systems, single-bath and double-bath, were used to compare their effects on fiber quality (Chowdhury et al., 2021).

Scouring Concentration

Increasing the concentration of sodium hydroxide (NaOH) during scouring significantly affected the jute fibers. At a lower NaOH concentration of 5 g/L, the fibers maintained their breaking strength with minimal loss (Karim et al., 2020) as shown in table 2. However, as the concentration rose to 20 g/L and 40 g/L, there was a marked reduction in breaking strength (Miah & Rahman, 2023). This decline is attributed to the aggressive removal of lignin and hemicelluloses, which are critical for maintaining fiber integrity (Hossain et al., 2019). The weight loss of the fibers increased proportionally with NaOH concentration, reaching a peak at 40 g/L (Zaman & Islam, 2024). This suggests that higher NaOH concentrations enhance impurity removal but at the expense of fiber strength (Ali et al., 2021& Abdul et at., 2013).

Impact of M Ratio and Treatment Time

The M ratio also played a crucial role in the effectiveness of the scouring process. At an M ratio of 1:10, the fibers experienced significant weight loss and strength reduction due to more extensive chemical exposure (Chowdhury et al., 2023 & Abdel et al., 2013). In contrast, at an M ratio of 1:40, the scouring effect was less pronounced, resulting in lower weight loss and better preservation of fiber strength (Nahar & Rahman, 2022). Treatment duration was another important factor; fibers treated for 30 minutes retained more of their mechanical strength compared to those treated for 40 minutes (Islam & Ahmed, 2022). Prolonged treatment time led to further degradation of the fibers, indicating a limit to the duration of effective scouring (Sarker & Islam, 2024).

Bleaching Concentration

The concentration of hydrogen peroxide (H_2O_2) during bleaching similarly influenced fiber properties. At a concentration of 0.5 g/L, the fibers showed minimal reduction in breaking strength, suggesting that lower concentrations are less damaging (Mohiuddin & Rahman, 2023). However, as the concentration increased to 1.0 g/L and 1.5 g/L, there was a notable decrease in breaking strength, with the most significant reduction occurring at 1.5 g/L (Karim et al., 2024). This indicates that higher H_2O_2 concentrations degrade the fiber structure more severely (Ahmed & Hossain, 2022). Weight loss also increased with higher H_2O_2 concentrations, with the greatest loss observed at 1.5 g/L, reflecting more effective removal of residual impurities and lignin (Hossain et al., 2019) as shown in table 3.

Comparison of Single-Bath and Double-Bath Systems

The comparison between the single-bath and double-bath systems revealed that the single-bath system, which combined scouring and bleaching in one step, resulted in higher overall weight loss but a greater reduction in fiber strength (Khan et al., 2020), as shown in figures 7 & 8. This system's efficiency in impurity removal came at the cost of fiber integrity. In contrast, the double-bath system, where scouring and bleaching were performed in separate stages, offered a better balance between impurity removal and strength retention (Chowdhury et al., 2021). The separate treatments allowed for more precise control, leading to less fiber degradation and a more controlled reduction in weight loss (Miah & Rahman, 2023).

Discussion

The study's findings offer valuable insights into optimizing the scouring and bleaching processes for Bangla White (BWB) A-grade long jute fibers, highlighting the interplay between chemical concentrations, M ratios, treatment durations, and processing systems (Chowdhury et al., 2021). This discussion delves into the implications of these results, their relevance to jute fiber processing, and potential avenues for further research.

Table 1. Weight of fiber before and after NaOH treatment

NaOH (g/l)	Without Treatment	M:L=1:10, Time 30 min	M:L=1:10, Time 40 min
5	0.6	0.51	0.48
10	0.6	0.46	0.43
15	0.6	0.42	0.4
20	0.6	0.41	0.38
40	0.6	0.40	0.35

Table 2. Breaking Load at different concentrations of NaOH, M: L, Time at 90℃

S/L	Concentration of NaOH (g/l)	Breaking Load (gm)				
		Without Treatment (gm)	M: L 1:10		M: L 1:40	
			Time 30 Min	Time 40 Min	Time 30 Min	Time 40 Min
1	5	85-95	45-55	25-30	55-60	20-25
2	10		15-25	4.5-10.5	35-45	24-28
3	15		10-15	3.5-4.5	20-30	15-20
4	20		15-20	3.5-4.5	20-30	15-20
5	40		8-15	3.5-4.5	15-20	10-15

Table 3. Breaking Load at different concentration of H_2O_2, M: L, Time at 90℃

S/L	Concentration of H_2O_2 (g/l)	Breaking Load (gm)				
		Without Treatment (gm)	M: L 1:10		M: L 1:40	
			Time 30 Min	Time 40 Min	Time 30 Min	Time 40 Min
1	0.5	85-95	15-25	15-20	20-28	15-25
2	1.0		20-30	20-30	20-25	20-30
3	1.5		25-35	25-30	30-35	30-40

Table 4. Breaking Load at 90℃ and 40 min (Double Bath Scouring and Bleaching)

Breaking Load without chemical treatment	Breaking Load when M: L = 1:10		Breaking Load when M: L = 1:40	
	0.5 g/L H_2O_2 and 20 g/L NaOH	1 g/L H_2O_2 and 20 g/L NaOH	0.5 g/L H_2O_2 and 20 g/L NaOH	1 g/L H_2O_2 and 20 g/L NaOH
85 – 95 gm	10 - 20 gm	4 – 15 gm	12 – 18 gm	15 – 20 gm

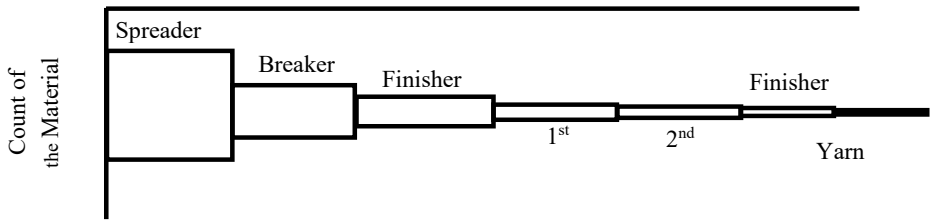

Figure 1. Relative counts in the jute process

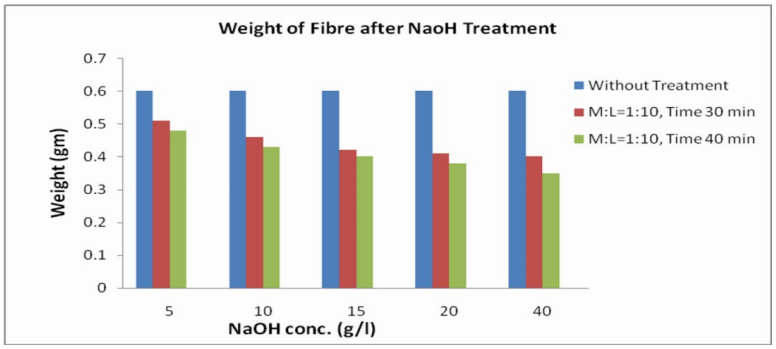

Figure 2. Fiber Weight Changes Due to Different NaOH Concentrations

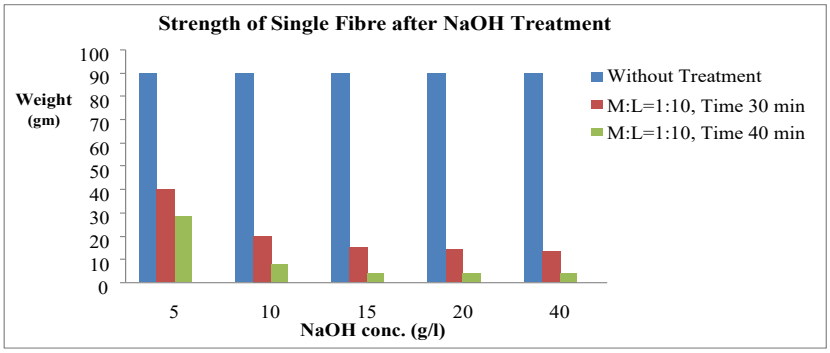

Figure 3. Single fiber strength after NaOH treatment at M: L 1:10

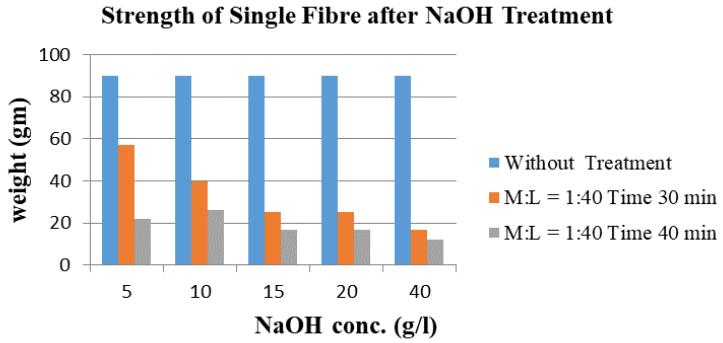

Figure 4. Single fibre strength after NaOH treatment at M: L 1:40

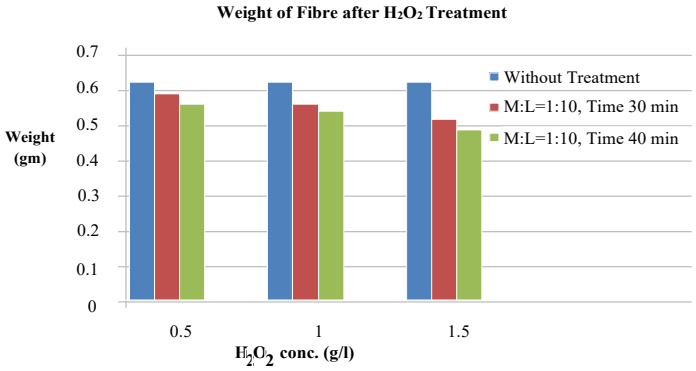

Figure 5. Fiber Weight Changes due to different H_2O_2 Concentrations

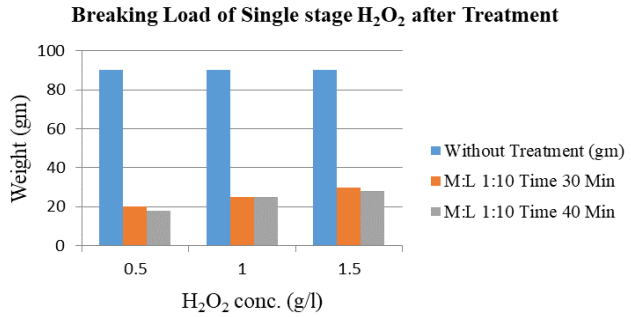

Figure 6. Effect of Breaking Load of after H_2O_2 Treatment on Jute Fibre

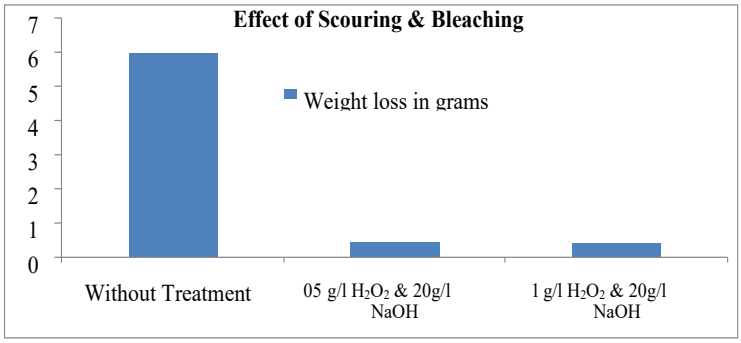

Figure 7. Effect of double bath scouring and bleaching on the fiber weight

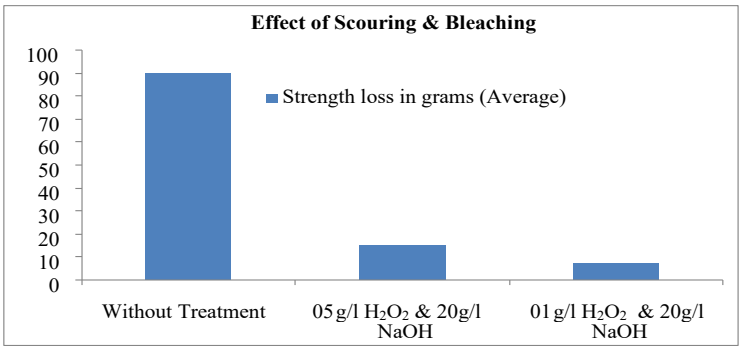

Figure 8. Effect of double bath scouring and bleaching on the single fiber strength

The observed reduction in breaking strength with increasing NaOH concentration aligns with the known effects of scouring agents on fiber properties (Ali et al., 2021) as shown in table 1. Sodium hydroxide effectively removes lignin and hemicelluloses, which are essential for maintaining the mechanical strength of jute fibers (Miah & Rahman, 2023) as shown in figure 1. At higher concentrations, NaOH aggressively dissolves these components, leading to significant fiber degradation (Hossain et al., 2019). The weight loss observed at higher NaOH concentrations underscores the effectiveness of scouring in removing impurities but also highlights the trade-off between impurity removal and fiber integrity (Zaman & Islam, 2024). This finding is consistent with previous studies that report similar effects of alkaline scouring on natural fibers, suggesting that a balance must be struck to optimize both cleanliness and strength (Karim et al., 2020) as shown in figure 2.

The results regarding M ratio indicate that higher ratios, such as 1:40, are more favorable for preserving fiber strength (Nahar & Rahman, 2022). This can be attributed to reduced chemical concentration per unit of fiber, which lessens the extent of fiber degradation (Chowdhury et al., 2023). Conversely, a lower M ratio, such as 1:10, exposes fibers to higher chemical concentrations, leading to increased weight loss and reduced strength (Rahman, 2021). These findings emphasize the importance of optimizing the M ratio to achieve effective scouring without compromising fiber quality (Islam & Ahmed, 2022) as shown in figure 3.

The effect of treatment duration also highlights a critical aspect of fiber processing (Sarker & Islam, 2024). The reduction in strength with extended treatment times suggests that prolonged exposure to scouring and bleaching agents exacerbates fiber degradation (Mohiuddin & Rahman, 2023). This observation supports the need for careful control of processing times to prevent excessive fiber damage (Hossain et al., 2019). Previous research has similarly documented the detrimental effects of prolonged chemical treatment on natural fibers, reinforcing the importance of optimizing treatment duration to maintain fiber properties (Karim et al., 2024) as shown in figure 4.

The impact of hydrogen peroxide concentration on fiber strength and weight loss is consistent with its role as a bleaching agent (Miah & Rahman, 2023). Higher concentrations of H_2O_2 result in more aggressive bleaching, which leads to greater fiber degradation and weight loss (Chowdhury et al., 2021). This effect is due to the oxidative action of hydrogen peroxide, which can weaken the fiber structure by breaking down the cellulose and lignin components (Ahmed & Hossain, 2022). The results indicate that while higher concentrations of H_2O_2 improve bleaching efficiency, they also compromise fiber strength (Karim et al., 2024). These findings highlight the need for a balance between bleaching effectiveness and fiber preservation, similar to findings reported in studies on other natural fibers (Ali et al., 2021) as shown in figure 5.

The comparison between single-bath and double-bath systems reveals important considerations for fiber processing (Khan et al., 2020). The single-bath system, which combines scouring and bleaching in one step, is efficient but results in more significant fiber degradation (Chowdhury et al., 2021). This efficiency comes at the cost of reduced mechanical strength, which is a critical factor for applications requiring robust fibers (Miah & Rahman, 2023). On the other hand, the double-bath system, which separates scouring and bleaching, allows for more controlled processing and better preservation of fiber strength (Chowdhury et al., 2023). The results suggest that the double-bath system is preferable for maintaining fiber integrity while achieving effective impurity removal (Khan et al., 2024) as shown in table 4.

The study's findings underscore the need for careful optimization of scouring and bleaching parameters to balance impurity removal with fiber strength (Ali et al., 2021). The optimal conditions identified moderate NaOH and H_2O_2 concentrations, an M ratio of 1:40, and a treatment time of 30 minutes provide a framework for achieving high-quality jute fibers with minimal degradation (Karim et al., 2024). These results have practical implications for the jute industry, where maintaining fiber strength is crucial for producing durable and high-performance textiles (Zaman & Islam, 2024) as shown in figure 6.

Future Research Directions

Further research could explore the effects of other scouring and bleaching agents, as well as alternative processing techniques, to enhance fiber quality and processing efficiency. Additionally, investigating the impact of different jute varieties and their specific responses to scouring and bleaching treatments could provide further insights into optimizing fiber processing for various applications. Comparative studies with other natural fibers may also yield valuable information on best practices for fiber treatment and processing.

Conclusion

This study demonstrates that optimizing scouring and bleaching conditions significantly impacts the quality of Bangla White (BWB) A-grade long jute fibers. The findings reveal that moderate concentrations of NaOH and hydrogen peroxide, an M ratio of 1:40, and a treatment duration of 30 minutes balance effective impurity removal with minimal fiber degradation. The double-bath system, which separates scouring and bleaching, proves superior in preserving fiber strength compared to the single-bath system. These results underscore the importance of carefully adjusting processing parameters to maintain the mechanical properties of jute fibers while achieving the desired cleanliness. This research provides

valuable insights for improving jute fiber processing, with potential implications for enhancing the quality and performance of jute-based textiles in industrial applications.

Author contributions

M.B.H. conceptualized the project and developed the methodology. A.S.S. conducted formal analysis, and drafted the original writing. M.S.F. contributed to the methodology, conducted investigations, provided resources, visualized the data. E.H. contributed to the reviewing and editing of the writing.

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Competing financial interests

The authors have no conflict of interest.

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