

Experimental Investigation on the Spinnability of Chemically Treated Banana Fibres and their Blends with Spun Silk

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Abstract: Banana fiber, a natural bast fiber obtained from the pseudo-stem of post-harvest banana plants, is an eco-friendly and abundant lignocellulosic material with significant potential in textile applications. However, its high content of lignin, hemicellulose, and pectin contributes to stiffness, low flexibility, and poor cohesion, posing challenges in yarn production. This study aims to improve the spinnability of banana fibers through various chemical treatments using sodium hydroxide (NaOH), hydrogen peroxide (H₂O₂), sodium carbonate (Na₂CO₃), and Levocol agents. The treatments were applied at different concentrations, temperatures, and durations to assess their effects on fiber softness, fineness, and overall processability. Results indicated that optimized chemical treatments effectively removed non-cellulosic components and improved fiber pliability, enabling better mechanical handling. Further, banana fibres were cut into staple length and blended with spun silk fibres in various proportions (50:50, 70:30, and 80:20) to facilitate processing in a ring spinning system. Among the blends, the 70:30 spun silk to banana fiber ratio exhibited the best spinnability, minimal fiber damage, and favourable yarn properties. This study demonstrates the potential of chemically modified banana fibers, in suitable blends, for sustainable yarn production and supports their application in eco-friendly textile development.

Keywords: *Banana Fibres; Spinnability; Chemical Treatments; Silk Blends; Yarn Properties.*

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I. INTRODUCTION

Natural fibres are existing as promising alternate to synthetic fibres due to their eco-friendliness, biodegradable, and with appropriate technology adoption it can become sustainable activity. These fibres are characterized by high strength, low density, excellent moisture absorbency, breathability, and superior comfort. Additionally, their biodegradability, renewability, and low-cost processing make them highly suitable for sustainable product development.

In response to growing environmental concerns and industrial demands for eco-friendly textiles, the use of natural fibres in technical textiles has gained momentum. Many of these fibres are derived from agricultural byproducts, turning potential waste into valuable raw materials.

Among natural fibers, banana fiber stands out due to its abundance and potential to be extracted from post-harvest banana plant especially in pseudo stem. Most of the farmers are dumping this stem as waste or burning them, this leads to increase in pollution and produce biomass which is harmful to the nature, for every 1 ton of fruit nearly 4 tons of debris (banana plant waste) is generated.

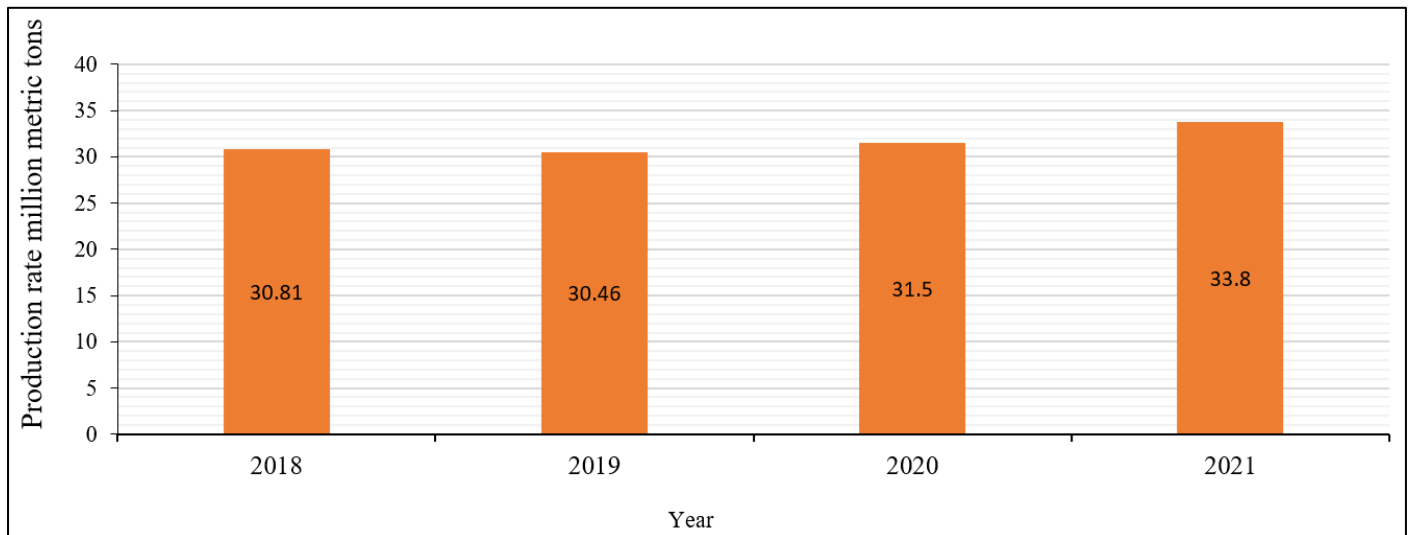


Fig 1 Banana Production Rate

Utilization of agricultural residues may have significant benefits for the environment and the agricultural community by preventing incineration on the field and by providing extra value to agricultural crops (Hafez S. Hawas). As a cellulose-based bast fiber, it offers a sustainable, recyclable, and locally available resource for developing green textile products. The

banana fiber consists of thick-walled cell tissue, bonded together by natural gums and is mainly composed of cellulose, hemicelluloses and lignin, etc., However, to unlock its full potential in spinning and textile applications, specific treatments are needed to overcome its inherent stiffness and processing challenges.

Table 1 Chemical Compositions of Banana Fibers

Substances (%)	Raw Banana Fibers
Cellulose	58.5
Hemicellulose	13.1
Pectin	4.3
Lignin	7.4
Fats & wax	1.2
Ash content	2.6
Moisture	13

Source: (Lenindy D)

➤ Extraction of Banana Fibers

Banana fibres are extracted from the pseudo-stem of the banana plant after the fruit is harvested and the plant becomes unusable. Several extraction methods exist viz; retting, followed by chemical, and mechanical treatment. Among these, mechanical extraction using a fibre extractor or decorticator machine is widely adopted for its efficiency and suitability for bulk processing. As retting is time consuming and laborious in nature, most of the processors prefer chemical and mechanical treatment.

In mechanical extraction method, the banana stem is first cleaned by removing leaves and damaged outer sheath layers. The stem is then cut into chunks approximately 90–120 cm in length, and the inner sheaths are stripped and fed into a fibre extractor machine. The machine separates the fibres from the sheaths effectively. Once extracted, the fibres are thoroughly washed and sun-dried for around 48 hours to ensure the suitability for further processing. (Amanjot Kaur).

➤ Banana Fibers and its Treatment:

Coarse texture, high lignin content, and low flexibility of banana fibres restricts them in direct utilization during yarn

production. necessitating appropriate chemical treatments to enhance its spinnability. Chemical modifications such as alkali scouring, bleaching, and softening have shown improvements in fiber fineness and compatibility with other textile-grade fibers. Several studies have explored the potential of banana fibers as a sustainable alternative in textiles and composites, focusing on extraction methods, chemical treatment, and performance improvement.

Tholkappiyan E. (2016) reported that combined treatments using NaOH, H₂O₂, and Na₂CO₃ significantly improved the fineness and spinnability of banana fibers, achieving a fineness of 5.8 tex, which is adequate for yarn blending and spinning applications. Similarly, Kiruthika A. V. (2009) observed that while untreated banana fibers exhibited higher tensile strength, selective chemical treatments could tailor the fiber's mechanical and thermal behavior to meet specific processing needs in the textile industry. Yoga Milani et al. (2016) emphasized that structural and morphological studies are crucial to understanding the behavior of banana fibers post-treatment and their suitability for yarn formation. Ebisike et al. (2013) examined chemical retting using varying concentrations of NaOH, noting its effectiveness in lignin

removal and fiber separation, though excessive treatment affected fiber strength. Joshi et al. (2018) used enzymatic hydrolysis to extract nano-cellulose from banana stems, achieving enhanced crystallinity and thermal properties, suggesting application in functional and composite materials. Doshi and Karolia (2016) optimized bleaching processes using hydrogen peroxide and sodium hypochlorite, finding that combined treatments improved whiteness and hand feel while retaining fiber strength. Mamun et al. (2021) compared chemical and eco-friendly treatments, introducing banana stem ash as a natural scouring agent with comparable effectiveness, promoting sustainable processing alternatives. Velumani et al. (2021) studied alkali-treated and silicon-softened banana fibers in cotton blends, observing improved abrasion resistance with increased banana content but reduced softness and bursting strength. This study aims to explore various chemical treatments on banana fibers and evaluate their impact on the spinnability and quality of the resulting blended yarns.

II. MATERIALS AND METHODS

➤ Materials

The raw banana fibres (sourced locally from TamilNadu), Spun silk (Spinning Mill Mysore) used as blending fibres. The chemicals viz., Sodium Hydroxide pellets (NaOH), Sodium Carbonate (Na_2CO_3), Hydrogen Peroxide (H_2O_2), levocol CLFD, and levocol CSQ Wetting and scouring agents (Resil Chemicals & other local stores from Karnataka).

➤ Methodology

• Mechanical Opening of Banana Fibres:

In preliminary stage, fibres are need to be get opened. As raw banana fibres having high stiffness and bunch of

fibres are stucked together due to the previous stages. This opening process carried in willowing coir opening machine, initially the bundle of fibres are longer in length, so these fibres are cut into 10-15cm and this process is repeated 3 times for optimum opening of fibres. The fibres are manually spread over the feed lattice and fed through feeding rollers then passes to the beater. The processed fibres are more open and cleaned.



Fig 2 Banana Fibres Opening in Willowing Coir Opening Machine

• Chemical Treatment of Banana Fibres:

The banana fibres were treated with alkali solutions such as NaOH, Na_2CO_3 , and H_2O_2 at varying concentrations, as shown in table 2. The treatments were carried under controlled conditions, maintaining a material-to-liquor ratio of 1:40, with specific temperatures and durations. Multiple trials were carried out to determine the optimum chemical treatment. In this study, the effects of each chemical treatment were evaluated and compared to identify the most suitable process for preparing the fibres for subsequent spinning.

Table 2 Banana Fibre Treatment

Trial no.	NaOH Conc.	Time(min)	Temperature (°C)	pH
1	15%	60	90	9-10
2	15%	24hrs	Room temp.	9-10
3	12 g/l	60	90	9-10
4	10%	60	100	9-10
5	10%	60	85	9-10
6	10%	180	Room temp.	9-10
7	5%	60	100	9-10
8	5%	60	80	9-10
9	NaOH 10% + Na_2CO_3 5%	45	70	10
10	NaOH 10% + Na_2SO_4 2%	120	100	9-10
11	NaOH 5% + Soap 10%	60	80	9-10
12	10%	120	40	9-10
13	10%	60	60	9-10
14	10%	45	70	9-10
15	5%	60	60	9-10
16	5%	24hrs	40	9-10

Second experiment were carried out using a combination series of chemical treatments, including scouring - bleaching, alkalization - bleaching - re-alkalization and Alkali treatment - bleaching. These treatments

collectively aimed to alter the physical and chemical characteristics of the banana fibres, making them more suitable for the spinning process using conventional machinery.

Table 3 Combination of Chemical Treatment on Banana Fibres

Treatment name	Chemical used	Time & temp.	pH
Scouring & bleaching	Soda ash-4g/l H ₂ O ₂ -1gp/l Stabilizer-0.1g/l Wetting agent	80°C, 60min	10-11
Alkalization, Bleaching, & Re-alkalization	4% NaOH H ₂ O ₂ 2% 4% NaOH	85°C, 90min 85°C, 25min 85°C, 60min	9-10 10-11 9-10
Alkali treatment & bleaching	NaOH 10%, H ₂ O ₂ 2%	Room temp. 120min 80-90°C, 1hr	10-11
	NaOH 5%, H ₂ O ₂ 2%	60°C, 1hr 85°C, 1hr	10-11
	NaOH 5% H ₂ O ₂ 3%	85°C, 1hr 85°C, 1hr	10-11

Third Experiment was carried out using Levocol CLFD and Levocol CSQ at different concentrations to remove surface impurities and improve fibre softness. A combined scouring and bleaching treatment were also performed using

Levocol agents along with hydrogen peroxide to achieve better fibre brightness and cleanliness. Each treatment was conducted under controlled pH and temperature conditions, as detailed in the table 3.

Table 4 Chemical Treatment of Banana Fibres Using Levocol Scouring Agents

Treatment name	Chemical used	Time & temp.	pH
Scouring	Levocol CLFD 2% Levocol CSQ 0.2%	80-85°C, 30min	6-7
	Levocol CLFD 4% Levocol CSQ 0.4%	80-85°C, 30min	6-7
Scouring with bleaching	Levocol CLFD 1.5% Levocol CSQ 0.5% & H ₂ O ₂ 2%	Room temperature, 12hrs	6-7

- *Standardization of Chemical Treatment for Banana Fibres*
For bulk trial following recipe was selected from the small quantity trials. Where, levocol CLFD, levocol CSQ,

along with H₂O₂ was selected and to avoid adverse effect of temperature, prolonged room temperature treatment was carried out for about 12hrs was preferred.

Parameter / Chemical	Specification / Value
M:L Ratio	1:30
Levocol CLFD	1.5%
Levocol CSQ	0.5%
H ₂ O ₂ + Stabilizer	2 ml/l
Temperature	Room temperature
Duration	12 hrs
pH	6-7

Scouring efficiency is obtained by using formula mentioned below:

$$\text{Weight loss\%} = \frac{W_i - W_f}{W_i} \times 100$$

Where, W_i is the initial weight of the fiber and W_f is the final weight of fiber i.e., after scouring.

- *Spinning Process of Banana Fibres*

The pre-treated banana fibres are taken for the spinning process, there is a slippage in banana fibers due to their filament nature. Hence, banana fibers are blended with fine staple silk fibres to increase cohesiveness between the fibers to produce better yarn. In this stage 100% banana fibers are

processed with roller clearance carding machine, and also blended with spun silk before the carding process. The fibers are blended manually by hand weight ratio of 50:50, 70:30, 80:20. The blended fibers are processed in standard commercial scale spinning system, which consist of two run in carding machine, to obtain better continues sliver. The draft of the carding machine is 2.3, and the sliver count is 0.256Ne. The output of carding is fed into the speed frame where the liner density of sliver is reduced by drafting. Then the rove is produced by speed frame machine and finally spun in ring frame with twist level of 600-650 turn/m and keeping spindle speed about 15000rpm.

Figure 3 shows images of the carded sliver obtained from different ratio of banana blends. In those blends, 70:30 blend ratio sliver gives suitability for further process in yarn production.



Fig 3 Carding Process



Fig 4 Slivers of Different Proportion of Blending Banana Fibres with Spun Silk

III. RESULTS AND DISCUSSION

➤ Effect of NaOH Concentration on Banana Fibers:

Table 5 Assessment of Scouring Treatment with NaOH

Sl no.	Test			Wt. loss %	Ratings	Grade
	NaOH (Con.)	Time (mins)	Temp. (°C)			
1	15%	60	90	24	1/5	Poor
2	15%	24hrs	RT	21	1/5	Poor
3	12g/l	60	90	28	1/5	Poor
4	10%	60	100	18	2/5	Better
5	10%	180	RT	19.2	3/5	Good
6	10% + 5% Na ₂ CO ₃	45	70	17.4	2/5	Better
7	10% + 5% Na ₂ SO ₄	120	100	19.3	2/5	Better
8	5%	60	100	17.4	2/5	Better
9	5%	60	80	17	3/5	Good
10	5%	60	60	16.5	4/5	Very good
11	5% + 10% soap	60	80	18	5/5	Excellent
12	5%	24hrs	RT	15	5/5	Excellent

In order to obtain optimum concentration of NaOH, banana fibres were treated with different concentration. However, excessive degradation, as seen in trials 1 and 3, resulted in poor fibre quality with harsh hand feel, leading to low ratings. In contrast, moderate treatment conditions such as 10% NaOH at room temperature for 180 minutes (Trial 5) showed balanced results, with satisfactory weight loss and improved absorbency, softness, and visual appearance.

The rating and grading of the treated banana fibres were based on subjective assessments carried out by industry experts and technical professionals, considering factors such as fibre based on visual, tactile, and absorbency assessments, ratings were assigned, and the best outcome was observed under milder alkali conditions, suggesting that prolonged exposure at lower concentration may be optimal for banana fiber scouring.

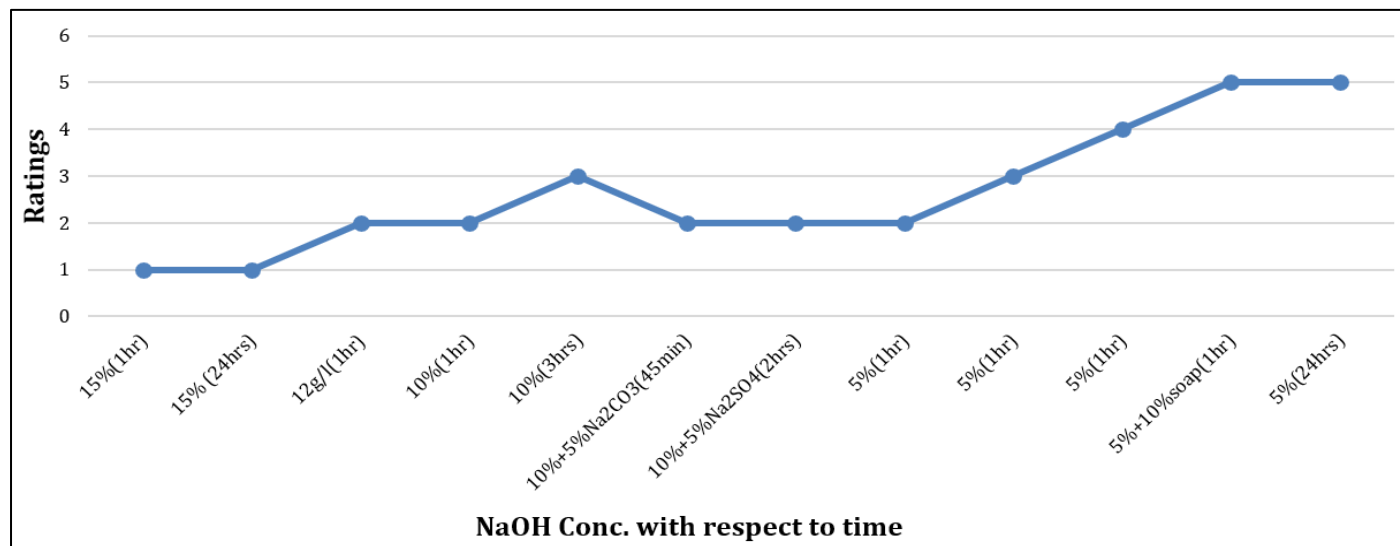


Fig 5 Effect of Time on Treatment with Varying NaOH Conc.

From the figure 5 we can observe that the effect of temperature and time of treatment with NaOH conc. the high temperature treated fibers were damaged and reduces strength and weight loss percentage was exceeded, in 40-60°C treated fibers were showed better results and strong fibers and absorbency was more. The banana fibre had subjected to NaOH softening treatment this had shown good result with NaOH concentration of 5% and NaOH concentration with 10% soap. The reason can be attributed as low % concentration of NaOH gives a good softening to banana fibre.

➤ Effect of Temperature on Banana Fibre Treatment.

To determine the optimum processing temperature, banana fibers were treated at varying temperature levels using NaOH solutions. As shown in Figure 2, treatments at higher temperatures led to fiber damage, reduced strength, and excessive weight loss. Conversely, fibers treated at moderate temperatures (40–60 °C) exhibited improved absorbency, better softness, and structural integrity. Additionally, treatment with 5% NaOH combined with 10% soap resulted in effective softening, indicating that lower NaOH concentrations enhance fiber processability without compromising quality.

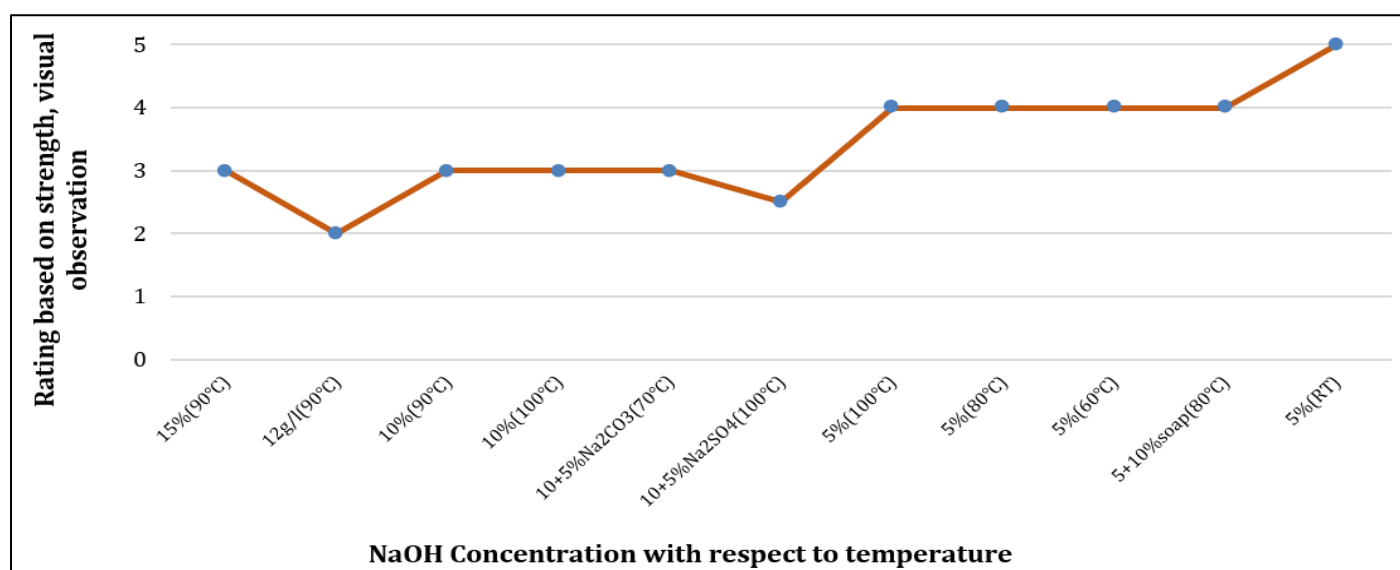


Fig 6 Effect of Temperature on Treatment with Varying NaOH Conc.

➤ *Effect of Combination Chemical Treatment on Banana Fibres:*

Table 6 Assessment of Combination Chemical Treatment of Banana Fibres

Treatment name	Chemical used	Time & temp.	Water absorbency	Ratings
Scouring & bleaching	Soda ash-4g/l H2O2-1gp/l Stabilizer-0.1g/l Wetting agent	80°C, 60min	Good	3/5
Alkalization, Bleaching, & Re- alkalization	4% NaOH	85°C, 90min	Better	2/5
	H2O2: NaOCl	85°C, 25min		
	4% NaOH	85°C, 60min		
Alkali treatment & bleaching	NaOH 10% + H2O2 2%	Room temp. 120min 80-90°C, 1hr	Excellent	5/5
	NaOH 5% + H2O2 2%	60°C, 1hr 85°C, 1hr	Excellent	5/5
	NaOH 5% + H2O2 3%	85°C, 1hr 85°C, 1hr	Good	3/5

Various treatment combinations involving alkali and bleaching agents were assessed to enhance the absorbency and handle of banana fibres. As shown in the table, the treatment with 10% NaOH and 2% H₂O₂ at room temperature followed by heating yielded the highest water absorbency, indicating excellent fibre opening and removal of impurities. Similarly, 5% NaOH + 2% H₂O₂ treatments at both 60°C and 85°C also performed very well, suggesting that even lower alkali concentrations, when combined with hydrogen

peroxide, can significantly improve fibre quality. On the other hand, multistep treatments involving alkalization, bleaching with NaOCl, and re-alkalization showed only moderate improvement (2/5), possibly due to fibre degradation or incomplete removal of non-cellulosic materials. Therefore, optimized one-bath alkali-bleach combinations proved more efficient and practical for enhancing the water absorbency and softness of banana fibers compared to multi-stage processes.

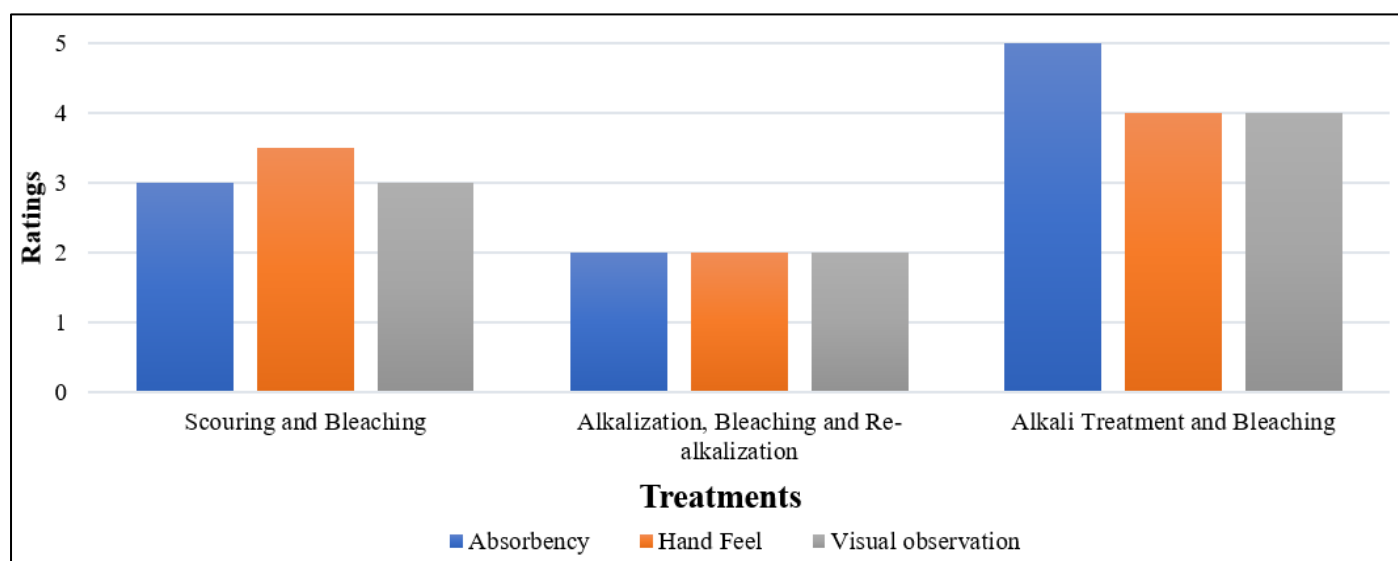


Fig 7 Combination Treatment of Banana Fibres

From Figure 7, it is evident that the absorbency of banana fibres is higher in scouring and alkali-treated samples compared to those subjected to re-alkalization. As the number of treatments increases, the fibres tend to lose strength and performance. Minimal wet processing is ideal to preserve the

natural strength and quality of banana fibres. Scouring is essential to remove lignin and rigidity, improving absorbency and hand feel, while bleaching primarily enhances fibre brightness.

Table 7 Chemical Treatment of Banana Fibers Using Scouring Agents

Treatment name	Chemical used	Time & temp.	Grade	Ratings
Scouring	Levocol CLFD 2% Levocol CSQ 0.2%	80-85°C, 30min	Good	3/5
	Levocol CLFD 4%	80-85°C, 30min	Very good	4/5

	Levocol CSQ 0.4%			
Scouring with bleaching	Levocol CLFD1.5% Levocol CSQ 0.5% & H ₂ O ₂ 2%	Room temperature, 12hrs	Excellent	5/5

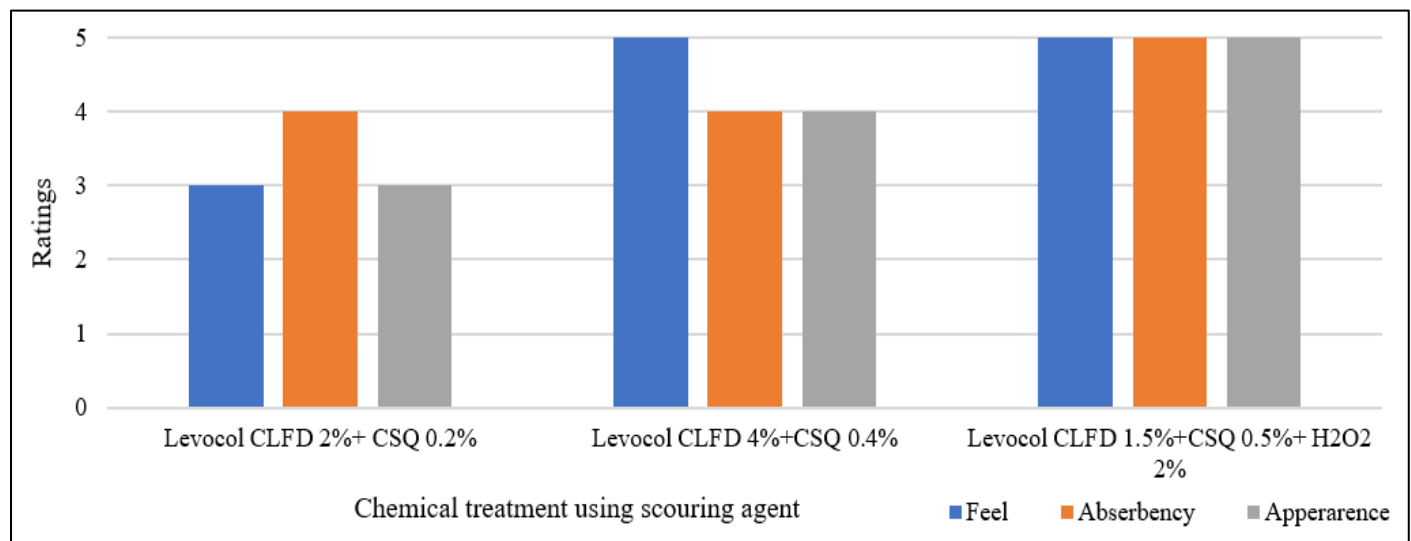


Fig 8 Chemical Treatment of Banana Fibres Using Scouring Agents

Maximum whiteness, minimum strength loss and maximum weight loss was observed by using Sodium hydroxide as alkali. Besides this another reason for optimizing sodium hydroxide is the fact that treatment with sodium hydroxide reduces thickness of banana fibres. From the above figure 3.5 it can be observed that, levocol CLFD is used as scouring treatment and levocol CSQ is used as sequestering agent improved the hand feel of banana fibre,

also it helps in removal of gummy substances of fibers and make fibers soft. Therefore, an experiment was planned to combine with H₂O₂ for its whiteness. This combination concluded to be successful as best results in terms of whiteness, softness and weight loss.

➤ *Banana Yarn and its Properties:*

Table 8 Yarn Specifications

Parameters	Values
Fibers used in yarn	Treated banana fibers blended with spun silk (30:70)
Type of machine used for spinning	Ring frame
Yarn count	18.5 Ne
Single yarn strength	3.76 g/tex
Yarn twist	22 TPI
Twist direction	'Z' twist

The blended yarn produced using a 70:30 ratio of spun silk to treated banana fibers on a ring frame spinning system demonstrated moderate spinning performance and acceptable yarn characteristics. The selected blend ratio was found to be optimal compared to other attempted blends 50:50 and 80:20, where the former showed poor sliver integrity and the latter had insufficient banana fiber content to impart the desired properties. The final yarn had a count of 18.5 Ne, a strength of 3.76 g/tex, and a twist of 22 TPI. However, several challenges were encountered during yarn formation. Notably, all blend ratios exhibited low fiber cohesion, which was especially apparent during the passage of the roving through the speed frame. In the 70:30 blend, fibers were observed to fall off, indicating that the binding between the silk and banana fibers was not sufficiently strong to withstand high drafting forces. This suggests a need for process optimization, such as modifying the drafting parameters, applying pre-treatment to improve fiber compatibility, or introducing a

binder fiber to enhance cohesion. Despite these issues, the 70:30 blend was the most viable option for producing a functional yarn with balanced mechanical and aesthetic properties.

IV. CONCLUSIONS

Banana fiber extracted from pseudo stem will have more lignin content it leads to fiber rigidity and can cause fiber breakages during spinning, so it need pre-treatment to soften fiber. Based on results of various chemical treatment conducted on banana fibres using NaOH, H₂O₂, and Levocol we have found that NaOH treated fibers has shown increase in fibre damage when it is subjected to high temperature and concentration, also observed that fibres are not scoured and softened completely. In LEVOCOL treatment the result shows effectively, banana fibres were scoured and bleached excellently and shows minimal strength loss, and scouring

treatment controls the percentage of fibre damage so based on the results we can conclude that the levocol scouring treatment shows desirable results of softening the banana fibers in those trials, concluding that the room temperature about 12hrs treatment shows best result. By consuming less amount of energy banana fibres were scoured in this present work.

The low cohesiveness of treated banana fibres, became essential in blending with other fibres to facilitate spinning. Among the blend ratios (50:50, 70:30, and 80:20), the 70:30 blend yielded the most balanced sliver, incorporating a significant proportion of banana fibre while maintaining processability. Yarn produced from this optimized blend showed a yarn count of 18.5 Ne and a single yarn strength of 3.7 g/tex. Despite this, the strength of the blended yarn remained relatively low, primarily due to fibre loss during spinning and poor fiber packing resulting from insufficient twist and the stiffness of banana fibres. The high hairiness observed further indicates challenges in achieving smooth yarn structure. These findings highlight the need for a standardized processing protocol-from extraction to chemical treatment-to improve fiber fineness and cohesiveness, which are crucial for achieving better yarn integrity, packing efficiency, and overall yarn performance.

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