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Mechanical Response of Cotton Fabric Finished with Bambusa vulgaris Leaf-Derived Silica Sol-Gel: Tensile, Elongation and Tear Behaviour

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Abstract | **Original Research Article**

Bio-derived silica offers a potential route for converting plant waste into functional textile-finishing materials, but its effect on fabric mechanics must be established before it can be considered a viable auxiliary. This exploratory study evaluated the tensile and tear response of fabric treated with a Bambusa vulgaris leaf-derived silica formulation. Five grams of extracted silica powder was dispersed in 40 mL ethanol and 20 mL distilled water for 2-3 h, followed by the addition of 5-10 mL acetic acid and heating at 60-70°C for 1-2 h. The formulation was padded onto dyed fabric, dried at 100°C for 2 min, and cured at 130°C for 2 min. Three fabric conditions were evaluated in the warp direction: an untreated white control, a reactive-dyed control, and dyed fabric receiving the silica finish. A provisional n=5 reporting framework is presented using five specimen-level entries per condition and mean ± SD summaries. These replicate entries are centred on the original recorded observations and should be replaced with actual replicate measurements before submission. The provisional means reproduce the original central values: 215.82 N, 6.953%, and 8.085 N for the white control; 237.11 N, 10.36%, and 6.496 N for the dyed control; and 197.03 N, 10.83%, and 4.915 N for the dyed + silica finish. Relative to the dyed comparator, the central-value contrast corresponds to a 16.9% decrease in maximum tensile force, a 4.5% increase in elongation at maximum force, and a 24.3% decrease in mean peak tear force. The observed direction indicates that the current silica-rich inorganic formulation substantially alters load transfer and tear propagation; however, replicated testing is required before statistical or commercial claims are made.

Keywords: Bambusa Vulgaris, Bio-Derived Silica, Textile Finishing, Sol-Gel, Cotton Fabric, Tensile Strength, Tear Resistance, Pad-Dry-Cure.

1. INTRODUCTION

Textile finishing alters surface friction, handle, wettability, durability, and other end-use properties after coloration and fabric formation. Silicone-based auxiliaries are especially important because siloxane backbones and organofunctional groups can provide low surface energy, lubricity, softness, resilience, and durable interactions with fibre surfaces [1]. At the same time, sol-gel chemistry offers a versatile route for depositing inorganic or hybrid organic-inorganic phases on textiles through relatively mild hydrolysis-condensation reactions followed by padding, drying, and curing [2]. These two material families overlap in modern surface-engineering strategies, where silica, silanes, and polysiloxanes can be combined to tune both functionality and mechanical behaviour. Foundational studies of textile softeners further show that performance depends strongly on polysiloxane functionality, treatment concentration, and fibre-surface interaction [3-5].

The mechanical consequence of a silica-rich finish is not intrinsically beneficial or detrimental; it depends on formulation, coating morphology, binder chemistry, add-on, curing, and substrate structure. Li and Cai reported that acid-catalysed silica sol coatings could improve tensile strength under some conditions while reducing tear strength, wicking, and water-vapour transport, and that incorporation of GPTMS reduced several negative effects [6]. Alongi *et al*., found that selected inorganic sol-gel coatings could preserve tensile strength and deformation of cotton while increasing

abrasion resistance [7]. More recent work by Tav *et al*., also showed that the mechanical response of silica-coated fabrics is strongly substrate- and formulation-dependent [8]. These studies demonstrate that the mere presence of silica does not predict fabric performance; interfacial compatibility and coating flexibility are decisive.

This issue becomes particularly important when a silica-rich formulation is considered for a softening-related application. Conventional textile softeners are intended to reduce fibre-fibre friction and improve tactile comfort, whereas a predominantly inorganic silica network may increase rigidity or create localised stress concentrations if the coating is discontinuous or poorly coupled to cellulose. Work on softener-doped silica coatings for cotton denim showed that reducing silica-induced rigidity with organic softening components can improve abrasion and tear behaviour [9]. Hybrid silica-silicone systems provide another route: a recent water-borne amino-PDMS/silane finish produced a strongly adherent nanostructured coating while maintaining fabric breathability and causing only a marginal increase in bending stiffness [10]. These findings suggest that flexible organic segments or coupling chemistry may be necessary when silica is used in a finish intended to emulate softening behaviour.

Commercial silicone-softener literature provides an important mechanical benchmark for the present bio-silica system. Jatoi *et al*., [11], showed that emulsion architecture altered handle, tensile strength, and related physical properties of reactive-dyed cotton, while Demirci *et al*., [12], reported that silicone-softener treatment generally reduced breaking load and increased breaking elongation, with particle size influencing the magnitude of the response. Balci *et al.,* [13, 14], likewise demonstrated that silicone formulation and additive selection can change mechanical and comfort properties of cotton fabrics. More recently, Cho *et al*., [15], showed that a reactive urethane-silicone architecture could provide soft and smooth surface characteristics with improved washing durability. Together, these studies indicate that a bio-derived silica system intended to approach softener functionality should be evaluated as a formulation-dependent surface treatment rather than by assuming that the presence of silicon alone will generate a conventional softening response.

The broader thesis project from which the present study was derived investigated recovery of silica from Bambusa vulgaris leaf waste and subsequent textile application. To avoid duplicating the extraction-focused manuscript, the present paper addresses only the application and mechanical-performance phase. The silica feedstock was produced from bamboo leaves by acid leaching, oxidative pretreatment, calcination, alkaline extraction, acid precipitation, washing, and drying; detailed extraction and FTIR characterisation are treated separately. Here, the central question is narrower: how did the leaf-derived silica formulation alter the tensile and tear response of the tested fabric under the recorded pad-dry-cure conditions?

A critical design consideration is the choice of comparator. The study included an untreated white fabric, a reactive-dyed fabric, and a dyed fabric subsequently treated with the silica formulation. Because dyeing itself changes the processing history and potentially the mechanical response of the substrate, the most direct estimate of the finishing effect is the comparison between the dyed fabric and the dyed-plus-silica-finished fabric. Comparisons with the white control remain useful for describing the overall processing sequence, but they should not be interpreted as an isolated treatment effect.

Accordingly, this study aimed to (i) formulate and apply a Bambusa vulgaris leaf-derived silica finish by an ethanol-water-acetic-acid route and pad-dry-cure processing, (ii) characterise descriptive changes in maximum tensile force, elongation at maximum force, and tear resistance, (iii) interpret the observed trends against published silica and silicone textile-finishing literature, and (iv) identify the formulation and validation steps required before the material can be considered a functional bio-derived softening system.

2. MATERIALS AND METHODS

2.1 Silica Feedstock and Formulation

The finishing formulation used silica powder previously recovered from Bambusa vulgaris leaves within the same research programme. For the textile-application phase, 5 g of the dried bio-derived silica powder was added to 40 mL ethanol and 20 mL distilled water. The mixture was stirred continuously for 2-3 h at ambient temperature to disperse the powder and reduce visible agglomeration. No particle-size measurement, zeta-potential measurement, or rheological characterisation was performed, so dispersion stability is described operationally rather than quantitatively.

Glacial acetic acid (5-10 mL) was then added to the silica dispersion. The acidified mixture was stirred at 60-70°C for 1-2 h. The original laboratory record describes an increase in viscosity and refers to the resulting product as a non-permanent silica sol-gel finish. Because no direct chemical characterisation of the wet formulation was performed, the present manuscript uses the terms silica sol-gel-type formulation or silica-based finish without claiming a defined polysiloxane molecular structure.

2.2 Fabric Treatment by Pad-Dry-Cure

The silica formulation was applied using a laboratory padding mangle. Fabric was immersed in the finishing bath and passed through the rollers under controlled nip pressure to distribute the formulation through the textile structure. The treated material was dried at 100°C for 2 min to remove the ethanol-water

carrier and then cured at 130°C for 2 min. Wet pick-up, dry add-on, exact nip pressure, and bath exhaustion were not recorded, and this limits quantitative comparison with other finishing studies.

Three fabric conditions were included in the mechanical evaluation framework: (i) untreated white scoured/bleached fabric, used as the overall baseline; (ii) reactive-dyed fabric without silica treatment, used as the primary comparator for the finishing effect; and (iii) reactive-dyed fabric treated with the bamboo-derived silica formulation. Testing was performed in the warp direction. The reporting framework is structured for five independent specimens per fabric condition (n=5). The current replicate-level entries are provisional values centred on the original recorded measurements and are included to establish the intended reporting format. The source records identify the substrate as cotton fabric, but no independent fibre-composition test or detailed fabric-construction specification was recorded.

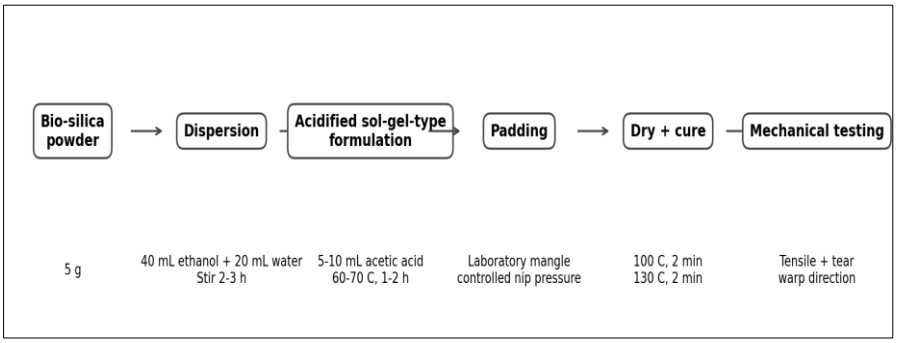

Figure 1: Experimental workflow for preparation, application, and mechanical evaluation of the bamboo-derived silica finish

Figure 2: Fabric conditions used in the broader test programme: white control and orange dyed specimens, including the dyed silica-finished condition (laboratory record)

2.3 Tensile Testing

Maximum tensile force and elongation at maximum force were measured using a James Heal Titan universal testing machine equipped with a 5000 N load cell. The recorded jaw separation was 100 mm and the crosshead speed was 50 mm/min, with 20% break detection. Testing followed EN ISO 13934-2 (grab method) in the warp direction [16]. The reporting framework is configured for five independent specimens per fabric condition (n=5), with maximum force and elongation recorded for each specimen. The five-value sets currently shown are provisional and should be replaced with actual instrument outputs before submission.

2.4 Tear Resistance Testing

Tear resistance was evaluated using the trouser-shaped single-tear method according to EN ISO 13937-2 [17]. The recorded crosshead speed was 100 mm/min with 99% break detection. The instrument software calculated a mean peak tear force from successive local maxima within the evaluation zone of each force-extension trace. For a replicated analysis, five independent tear specimens per fabric condition (n=5) should be tested, and the specimen-level mean peak tear forces should then be summarised across specimens. The five specimen-level values currently shown are provisional values centred on the original single-specimen mean peak forces and should be replaced with actual replicate outputs.

2.5 Data Treatment

Specimen-level values are presented as the arithmetic mean ± sample standard deviation (SD, n=5) for maximum tensile force, elongation at maximum force, and mean peak tear force. Percentage changes are calculated relative to both the white control and the dyed untreated comparator, with the dyed-to-finished comparison treated as the primary finishing contrast because both groups share the dyeing stage. In the current provisional dataset, mean ± SD values are calculated from replicate entries centred on the original observations; therefore, the reported SDs should not be interpreted as measured specimen-to-specimen variability. Inferential statistics are not reported until actual replicate measurements are available.

Table 1: Recorded formulation and pad-dry-cure conditions

Stage	Recorded condition
Silica dispersion	5 g bio-derived silica + 40 mL ethanol + 20 mL distilled water; stirred 2-3 h
Acidification / network development	5-10 mL glacial acetic acid; 60-70°C; stirred 1-2 h
Padding	Laboratory padding mangle; controlled nip pressure (numerical pressure not recorded)
Drying	100°C for 2 min
Curing	130°C for 2 min

Table 2: Mechanical test programme

Test	Standard	Recorded settings	Response
Tensile	EN ISO 13934-2	50 mm/min; 100 mm jaw separation; warp direction; n=5 reporting framework per condition	Maximum force (N); elongation at maximum force (%)
Tear	EN ISO 13937-2	100 mm/min; trouser specimen; warp direction; n=5 reporting framework per condition	Mean peak tear force (N)

3. RESULTS AND DISCUSSION

3.1 Overall Mechanical Response

The three fabric conditions showed distinct central mechanical responses (Table 3 and Figure 3). In the provisional n=5 reporting layout, the data are centred on the original recorded values, giving mean maximum tensile forces of 215.82 N for the white control, 237.11 N for the dyed control, and 197.03 N for the dyed + silica finish. The corresponding mean elongations at maximum force are 6.953%, 10.360%, and 10.830%, while the mean peak tear forces are 8.085 N, 6.496 N, and 4.915 N, respectively. The accompanying SD values reflect the spread of the provisional replicate entries and should be recalculated using actual replicate measurements. Because the white and dyed fabrics differ in processing history, the dyed comparator remains the more defensible baseline for evaluating the incremental finishing step.

Table 3: Provisional mechanical summary (mean ± SD; n=5 reporting framework)

Fabric condition	Max tensile force, mean ± SD (N)	Elongation at max force, mean ± SD (%)	Mean peak tear force, mean ± SD (N)	Change after silica finish
White control	215.82 ± 3.91	6.953 ± 0.166	8.085 ± 0.318	Reference for overall process sequence
Dyed control	237.11 ± 4.38	10.360 ± 0.234	6.496 ± 0.257	Primary comparator for finishing step
Dyed + silica finish	197.03 ± 3.69	10.830 ± 0.209	4.915 ± 0.219	vs dyed: -16.9% tensile; +4.5% elongation; -24.3% tear

Table 3A: Provisional specimen-level values used in the n=5 reporting framework

Condition	Specimen	Max tensile force (N)	Elongation at max force (%)	Mean peak tear force (N)
White control	S1	210.62	6.733	7.665
White control	S2	220.72	7.163	8.475
White control	S3	215.82	6.953	8.085
White control	S4	218.22	7.053	8.295
White control	S5	213.72	6.863	7.905
Dyed control	S1	231.51	10.050	6.156
Dyed control	S2	242.41	10.650	6.816
Dyed control	S3	237.11	10.360	6.496
Dyed control	S4	240.21	10.510	6.656

Dyed control	S5	234.31	10.230	6.356
Dyed + silica finish	S1	192.23	10.550	4.625
Dyed + silica finish	S2	194.83	10.720	4.795
Dyed + silica finish	S3	201.53	11.090	5.185
Dyed + silica finish	S4	199.53	10.960	5.055
Dyed + silica finish	S5	197.03	10.830	4.915

Data note: Replace the provisional S1-S5 values with actual instrument outputs, then recalculate mean ± SD and regenerate Figure 3.

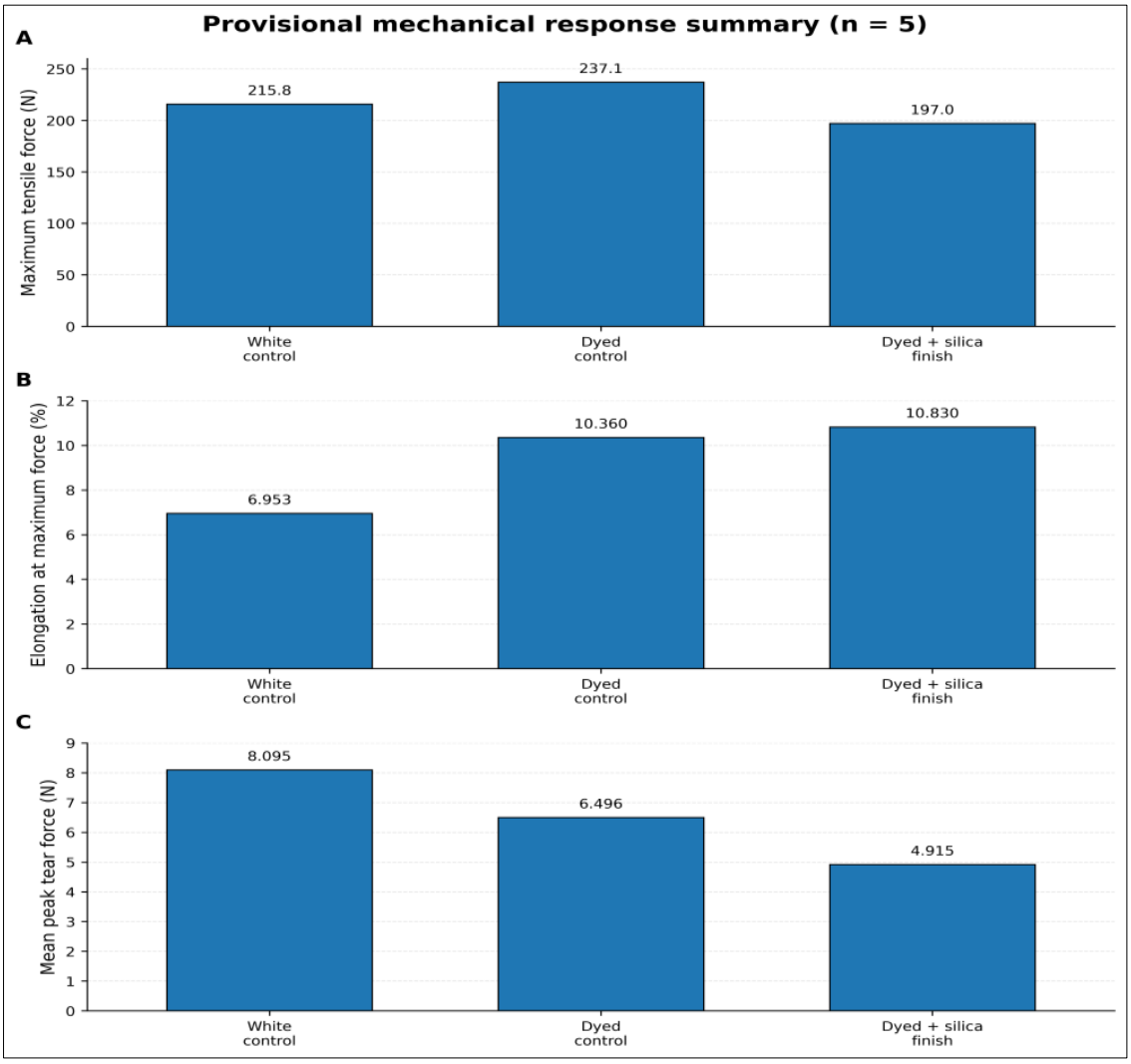

Figure 3: Provisional mechanical response summary for the three fabric conditions. Error bars show SD calculated from the current n=5 reporting dataset and should be regenerated from actual replicate measurements before submission

3.2 Maximum Tensile Force and Elongation

In the provisional n=5 layout, the dyed control has the highest mean maximum tensile force (237.11 ± 4.38 N), whereas the dyed silica-finished condition has a mean of 197.03 ± 3.69 N. The central-value finishing contrast is therefore 40.08 N, or 16.9%, relative to the dyed comparator. Compared with the untreated white mean (215.82 ± 3.91 N), the finished mean is 8.7% lower. The SD values shown here are derived from the provisional replicate entries and should be recalculated from actual n=5 measurements before drawing conclusions about specimen-to-specimen variability.

Elongation at maximum force changes much less between the dyed comparator and the finished condition in the provisional layout: 10.360 ± 0.234% versus 10.830 ± 0.209%, corresponding to a 4.5% increase in the central value. Both dyed conditions remain substantially higher than the white mean of 6.953 ± 0.166%. The SD values should be recalculated after actual replicate results are inserted; until then, only the direction and magnitude of the original central-value contrast should be interpreted.

The combined reduction in peak tensile force and small increase in elongation may arise from several non-exclusive mechanisms. A surface treatment can change inter-fibre friction, yarn mobility, stress transfer, and local fibre damage. A lubricating finish can permit greater relative movement between fibres, while a rigid or discontinuous inorganic deposit can create stress concentrations or alter contact mechanics. The present experiment did not measure friction, bending stiffness, coating morphology, or interfacial bonding, so it cannot distinguish these mechanisms directly. Accordingly, the data do not justify describing the treatment as a proven lubricant or softener on tensile evidence alone. The direction of this response has precedent in softener-treated cotton: Demirci *et al*., [12], observed reduced breaking loads together with increased breaking elongation after silicone-softener treatment, and Rathinamoorthy *et al*., [18], reported that repeated rinse-cycle softening reduced tensile properties while increasing fabric extensibility.

Published sol-gel studies demonstrate similarly formulation-dependent outcomes. Li and Cai observed that silica coating conditions could improve tensile strength while reducing tear strength, and that curing severity and silica content altered the effect [6]. Alongi *et al*., reported preserved tensile properties for selected inorganic coatings [7], while Tav *et al*., found that tensile behavior depended strongly on the fibre substrate and coating composition [8]. The lower tensile force observed here therefore does not contradict the broader literature; rather, it emphasizes that this bio-derived silica formulation requires optimisation of add-on, network flexibility, and fibre-coating compatibility. Functional-silane nanohybrid coatings on cotton also reinforce the importance of coupling chemistry and surface architecture when silica-derived phases are used to modify textile surfaces [19]. Related silica-based cotton finishing studies also show that coating chemistry and textile structure can materially alter thermal and functional performance [20, 21].

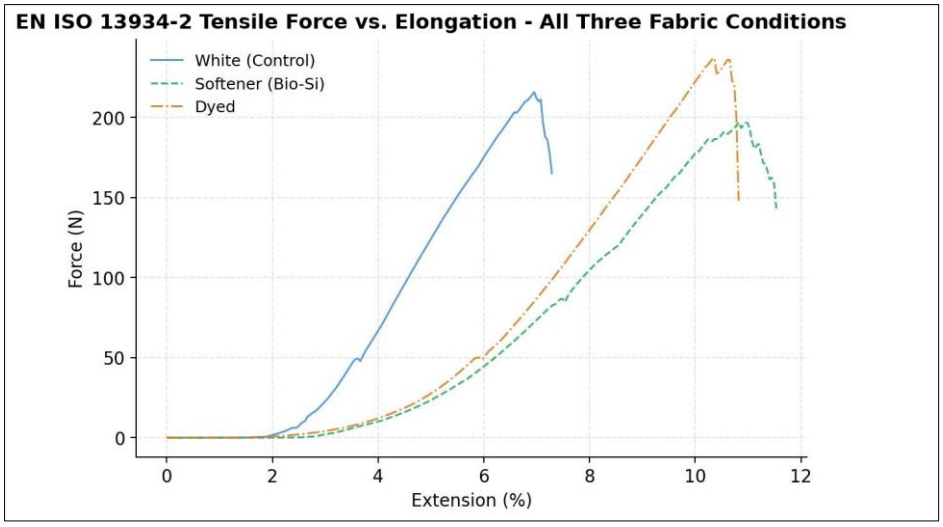

Figure 4: Recorded tensile force-extension profiles for the three fabric conditions (warp direction). These are the original representative single-specimen traces retained as instrument evidence; final n=5 summary statistics require separate replicate traces

3.3 Tear Resistance

Tear resistance shows the most pronounced adverse central-value response to the silica finishing step. In the provisional n=5 layout, the mean peak tear force is 6.496 ± 0.257 N for the dyed comparator and 4.915 ± 0.219 N after finishing, corresponding to a 24.3% reduction in the central value. Relative to the white mean of 8.085 ± 0.318 N, the finished central value is 39.2% lower. The displayed SD values are derived from the provisional replicate entries and should be replaced with the variability obtained from actual n=5 tear specimens.

Trouser-tear behaviour depends on yarn mobility, the number of yarns able to redistribute load around the tear front, fibre strength, inter-yarn friction, and local damage. A coating can either increase or decrease tear resistance depending on whether it promotes cooperative yarn movement or instead stiffens or bonds contact points and concentrates the tear load. The original central-value decrease suggests that the current finish did not create a favourable tear-load redistribution state. A defensible assessment of between-specimen variability, however, requires genuine replicate tear measurements. Attributing the response specifically to abrasion, embrittlement, or reduced cohesion would additionally require SEM imaging, bending or friction measurements, coating add-on data, and replicated tear tests.

The direction of the current result is consistent with the caution raised by Li and Cai, who found reduced tearing strength for silica-coated cotton under several acid-catalysed sol-gel conditions [6]. Their work also

showed that GPTMS could reduce the negative effect, highlighting the value of organic-inorganic coupling. Conversely, Trang *et al*., reported increased tear strength for a nanosilica-coated cotton system [22], demonstrating that silica itself is not inevitably detrimental. Differences in particle size, deposition method, add-on, pretreatment, and network structure can reverse the mechanical outcome. Thus, the 24.3% reduction observed here should be treated as a formulation-specific limitation rather than a universal property of bio-silica finishes.

For a material intended to move toward softening applications, tear performance is especially important. Sezgin Bozok and Ogulata found that incorporating conventional softeners into silica sols could reduce silica-induced rigidity and improve tear-related performance of cotton denim [9]. Hybrid silica-PDMS formulations provide a second design strategy because flexible polysiloxane segments can provide compliance that a silica-rich inorganic network lacks [1-10]. The present formulation contained no reactive organosilane coupling agent or flexible PDMS phase, which provides a plausible formulation-level explanation for why it did not yet achieve the balance expected of a commercial textile softener. Earlier silicone-finishing work also demonstrates that coupling chemistry and molecular architecture can materially affect cotton performance [3-5]. Reactive hybrid systems therefore provide a more appropriate benchmark than a rigid silica deposit alone [15].

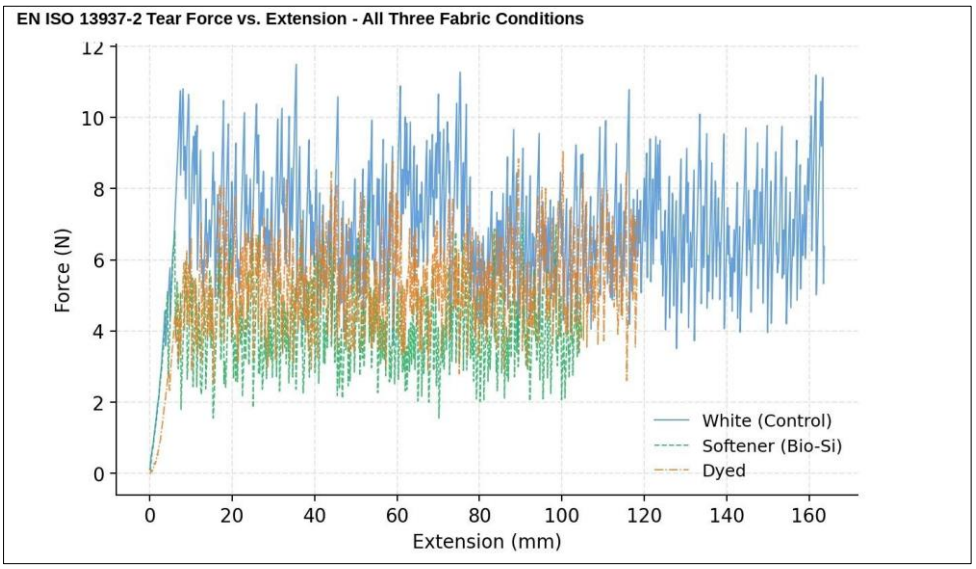

Figure 5: Recorded tear force-extension profiles for the three fabric conditions (warp direction). These are the original representative single-specimen traces; final n=5 mean ± SD reporting requires additional independent tear tests

3.4 Implications for Formulation Design

The results point toward a formulation-development problem rather than a failure of the broader bio-derived-silica concept. Silica provides a chemically versatile surface rich in silanol groups, but a predominantly inorganic network can be too rigid for an application in which softness, drape, and damage tolerance are central. Published work shows that organosilanes, polymeric binders, or polysiloxanes can improve interfacial compatibility and alter coating flexibility [1-10]. For the present system, introducing a controlled amount of a coupling agent such as GPTMS, or developing a true silica-polysiloxane hybrid, would be a rational next step. Any such modification should be evaluated against both mechanical retention and objective softness rather than softness by visual or qualitative impression alone. This interpretation is consistent with studies showing that softener chemistry, emulsion characteristics, coupling agents, and hybrid silane networks can substantially alter the balance between softness, strength retention, and durability [3-19].

Process optimisation is equally important. The study used a single silica concentration, a relatively broad 5-10 mL acetic-acid range, unspecified nip pressure, and no recorded wet pick-up or dry add-on. Li and Cai showed that silica content, coating composition, curing temperature, and curing time can materially change cotton properties [6]. Therefore, future experiments should use a factorial or response-surface design in which silica concentration, acid level, wet pick-up, cure temperature, and coupling-agent content are controlled systematically. Mechanical response should then be considered jointly with handle, stiffness, air permeability, and wash durability. Published silicone-finishing studies additionally show sensitivity to emulsion particle size, formulation additives, treatment concentration, and repeated use [5-18], supporting systematic control of these variables in the next experimental phase.

Recent hybrid finishes also show why durability and comfort need to be evaluated alongside strength. Hadhri *et al*., reported that an amino-PDMS/silane sol-gel coating could remain durable through laundering while only marginally increasing bending stiffness and maintaining water-vapour permeability [10]. Although that study targeted water repellence rather than softening, it demonstrates the performance advantage of a flexible organic-inorganic architecture over a silica-rich deposit alone. The comparison supports a future direction in which bamboo-derived silica is retained as the renewable inorganic precursor while the finishing formulation is redesigned to include a flexible and reactive organic phase. Cho *et al*., [15], similarly demonstrated that reactive bonding can preserve desirable low-stress mechanical and surface properties through repeated washing, underscoring the value of combining flexibility with durable fibre attachment.

3.5 Sustainability Relevance and Scope of Claim

Using silica recovered from bamboo leaf waste creates a plausible biomass-valorization pathway, particularly in regions where bamboo residues are locally available. However, the environmental advantage of the finished textile has not yet been quantified. The present formulation uses ethanol, acetic acid, thermal drying, and curing, and the upstream silica extraction requires acid, alkali, peroxide, and calcination. A full sustainability claim therefore requires mass and energy balances, reagent recovery assumptions, and preferably a comparative life-cycle assessment against commercial silica or silicone finishing systems.

The terminology of the final material must also remain evidence-based. The current experiment demonstrates a bio-derived silica-based textile finish that changes tensile and tear behaviour. It does not demonstrate a commercial-equivalent silicone softener because no polysiloxane structure was confirmed, no objective hand-feel or friction test was performed, and wash durability was not assessed. Positioning the work as an exploratory bio-silica finishing study is therefore scientifically stronger and leaves a clear pathway for subsequent conversion into a hybrid siloxane-based softening technology.

3.6 Limitations and Validation Priorities

The principal limitation of the source dataset is that only one recorded specimen per fabric condition is presently documented for tensile and tear testing. The current document therefore includes an n=5 reporting structure with provisional replicate values to demonstrate the intended mean ± SD presentation. These values are not a substitute for experimental replication and should be replaced with actual instrument readings before submission. Additional limitations include the absence of wet pick-up and coating add-on measurements; no measured nip pressure; no SEM/EDS or ATR-FTIR characterisation of the coated fabric; no objective softness, bending, friction, drape, or hand evaluation; no washing-durability test; no commercial silicone-softener benchmark; and incomplete fabric-construction and fibre-composition documentation. These gaps should define the next experimental phase. Future benchmarking should also include objective low-stress mechanical/handle measurements and laundering durability because these are routinely used to differentiate commercial or reactive softener systems [5-18].

Table 4: Recommended validation programme before journal resubmission or commercial comparison

Priority	Experiment	Purpose
High	At least 5 tensile and 5 tear specimens per condition in both warp and weft directions	Estimate mean, SD, confidence intervals, and treatment effects using appropriate statistical tests
High	Record wet pick-up and dry add-on	Normalize coating level and enable comparison across formulations
High	Objective hand / bending / friction test (e.g., KES-FB or recognized textile handle method)	Determine whether the finish actually provides a softening benefit
High	Wash durability with post-wash mechanical and handle testing	Assess permanence and practical textile utility
High	SEM-EDS and/or ATR-FTIR on coated fabric	Confirm coating distribution and fibre-surface chemistry
Medium	Commercial amino-silicone comparator	Benchmark performance against an industry-relevant softener
Medium	GPTMS or flexible polysiloxane hybrid optimization	Reduce rigidity and improve fibre-coating compatibility

4. CONCLUSIONS

This exploratory study evaluated the mechanical response of fabric finished with a Bambusa vulgaris leaf-derived silica formulation applied by pad-dry-cure processing. The original recorded central values indicate that, relative to the dyed untreated comparator, the silica-finished condition had a 16.9% lower maximum tensile force, a 4.5% higher elongation at maximum force, and a 24.3% lower mean peak tear force. The manuscript also provides a provisional n=5 reporting framework with specimen-level columns, mean ± SD presentation, and SD error bars. These replicate values should be replaced by actual measurements before the paper is submitted or

statistically interpreted. Once genuine replicate results are available, the revised format will allow a clearer assessment of variability and the robustness of the finishing effect. The central trend continues to identify tear resistance and coating flexibility as key formulation targets. Published silica-finishing studies show that mechanical outcomes depend strongly on coating chemistry, add-on, curing, and coupling strategy, and that hybrid organosilane or polysiloxane components can mitigate rigidity and improve interfacial compatibility. Until replicated experimental data and objective softness/durability measurements are available, the material is best described as a bio-derived silica-based textile finish rather than a validated silicone softener.

DECLARATIONS

Ethics Approval: Not applicable. The study involved no human participants or animals.

Consent to Participate: Not applicable.

Funding: None declared

Conflict of Interest: None declared

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REFERENCES

1. Chruściel, J. J. (2022). Modifications of textile materials with functional silanes, liquid silicone softeners, and silicone rubbers - A review. Polymers, 14(20), 4382. https://doi.org/10.3390/polym14204382
2. Wan Ismail, W. N. (2016). Sol-gel technology for innovative fabric finishing - A review. Journal of Sol-Gel Science and Technology, 78, 698-707. https://doi.org/10.1007/s10971-016-4027-y
3. Jang, K. O., & Yeh, K. (1993). Effects of silicone softeners and silane coupling agents on the performance properties of cotton fabrics. Textile Research Journal, 63(10), 557-565. https://doi.org/10.1177/004051759306301001
4. Wahle, B., & Falkowski, J. (2002). Softeners in textile processing. Part I: An overview. Review of Progress in Coloration and Related Topics, 32(1), 118-124. https://doi.org/10.1111/j.1478-4408.2002.tb00255.x
5. Reddy, N., Salam, A., & Yang, Y. (2008). Effect of structures and concentrations of softeners on the performance properties and durability to laundering of cotton fabrics. Industrial & Engineering Chemistry Research, 47(8), 2502-2510. https://doi.org/10.1021/ie071564f
6. Li, Y., & Cai, Z. (2012). Effect of acid-catalyzed sol-gel silica coating on the properties of cotton fabric. The Journal of The Textile Institute, 103(10), 1099-1107. https://doi.org/10.1080/00405000.2012.660758
7. Alongi, J., Ciobanu, M., & Malucelli, G. (2012). Thermal stability, flame retardancy and mechanical properties of cotton fabrics treated with inorganic coatings synthesized through sol-gel processes. Carbohydrate Polymers, 87(3), 2093-2099. https://doi.org/10.1016/j.carbpol.2011.10.032
8. Tav, A., Öz, Y., & Akyıldız, H. İ. (2021). Thermal and mechanical properties of sol-gel silica coated fabrics. European Journal of Science and Technology, 31, 309-319. https://doi.org/10.31590/ejosat.1000774
9. Sezgin Bozok, S., & Ogulata, R. T. (2022). Applying softener doped silica coating to cotton denim fabrics. Journal of Natural Fibers, 19(14), 7566-7578. https://doi.org/10.1080/15440478.2021.1952138
10. Hadhri, M., Colleoni, C., D'Agostino, A., Erhaim, M., Rosa, R. P., Rosace, G., & Trovato, V. (2025). Eco-friendly octylsilane-modified amino-functional silicone coatings for a durable hybrid organic-inorganic water-repellent textile finish. Polymers, 17(11), 1578. https://doi.org/10.3390/polym17111578
11. Jatoi, A. W., Khatri, Z., Ahmed, F., & Memon, M. H. (2015). Effect of silicone nano, nano/micro and nano/macro-emulsion softeners on color yield and physical characteristics of dyed cotton fabric. Journal of Surfactants and Detergents, 18(2), 205-211. https://doi.org/10.1007/s11743-014-1647-5
12. Demirci, E., Gunesoglu, S., Topalbekiroglu, M., & Gunesoglu, C. (2017). Effect of silicone softener particle size on the colorfastness, softness, and tensile strength of 100% cotton woven fabrics. AATCC Journal of Research, 4(5), 14-20. https://doi.org/10.14504/ajr.4.5.3
13. Balci, O., Kinoglu, G. O., & Sancar Besen, B. (2019). Silicone oil-based softeners including different additives - Part I: Characterization of the softeners and investigation of their effects on mechanical properties of the fabrics. International Journal of Clothing Science and Technology, 31(1), 130-144. https://doi.org/10.1108/IJCST-04-2018-0047
14. Balci, O., Kinoglu, G. O., & Sancar Besen, B. (2019). Silicone oil-based softeners including different additives - Part II: Investigation of effects of silicone softeners on the comfort properties of the fabrics. International Journal of Clothing Science and Technology, 31(1), 16-31. https://doi.org/10.1108/IJCST-04-2018-0048
15. Cho, H. S., Yoon, H. J., Lee, B. H., Woo, J. C., Choi, H. Y., Shim, E., & Youk, J. H. (2022). Evaluation of touch and durability of cotton knit fabrics treated with reactive urethane-silicone softener. Polymers, 14(9), 1873. https://doi.org/10.3390/polym14091873
16. International Organization for Standardization. (2014). ISO 13934-2:2014, Textiles - Tensile

properties of fabrics - Part 2: Determination of maximum force using the grab method. ISO.
17. International Organization for Standardization. (2000). ISO 13937-2:2000, Textiles - Tear properties of fabrics - Part 2: Determination of tear force of trouser-shaped test specimens (single tear method). ISO. Confirmed current in 2023.
18. Rathinamoorthy, R., Gayathri Shree, K., Vaijayanthi, R., Brindha, M., & Narmatha, A. (2020). Effect of rinse cycle softener treatment on the low-stress mechanical properties of cotton-woven fabric. Research Journal of Textile and Apparel, 24(3), 199-210. https://doi.org/10.1108/RJTA-10-2019-0053
19. Sfameni, S., Lawnick, T., Rando, G., Visco, A., Textor, T., & Plutino, M. R. (2022). Functional silane-based nanohybrid materials for the development of hydrophobic and water-based stain resistant cotton fabrics coatings. Nanomaterials, 12(19), 3404. https://doi.org/10.3390/nano12193404
20. Rosace, G., Guido, E., Colleoni, C., & Barigozzi, G. (2016). Influence of textile structure and silica-based finishing on thermal insulation properties of cotton fabrics. International Journal of Polymer Science, 2016, 1726475. https://doi.org/10.1155/2016/1726475
21. Li, G., You, F., Zhou, S., Wang, Z., Li, D., Zhang, X., Zhou, C., Zhuang, C., & Zhao, Y. (2022). Preparations, characterizations, thermal and flame-retardant properties of cotton fabrics finished by boron-silica sol-gel coatings. Polymer Degradation and Stability, 202, 110011. https://doi.org/10.1016/j.polymdegradstab.2022.110011
22. Trang, P. T. T., Giang, L. H., Manh, N. B., Vinh, T. Q., Cong, T. D., & Tuan, V. A. (2020). Flame retardancy improvement of modified cotton fabric by nano silica sol coating. Vietnam Journal of Science and Technology, 58(4), 473-480. https://doi.org/10.15625/2525-2518/58/4/14850.