



PROTEASE-BASED ENZYME PRESERVATION OF ASO-OKE FABRICS FOR THEATRE AND FILM

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<https://doi.org/10.70118/ajaas.032606010.26>

ABSTRACT

Aso-oke fabric, a handwoven textile indigenous to the southwestern region of Nigeria, is closely associated with Yoruba cultural heritage. Beyond its aesthetic quality, the fabric is valued for its durability, thermal regulation, high moisture absorption capacity, and relatively low flammability, making it particularly suitable for performance environments, especially those depicting epic and cultural narratives. However, its dense weave structure and organic fiber composition render it vulnerable to microbial infestation, odor retention, and gradual degradation under conditions of actors repeated wear, and perspiration in stage and film productions. These challenges necessitate innovative preservation strategies that will maintain the functional integrity and cultural authenticity of the textile. The study investigates the potential of a protease enzyme, Subtilisin, as a sustainable textile treatment for preserving Aso-oke fabric in order to enhance its physical and aesthetic durability for theatre and film costumes. Controlled laboratory experiments evaluated the effects of the enzymatic treatment on colour retention, surface morphology, microbial load reduction, and structural resilience following repeated simulated usage cycles, using standard textile testing and microbiological analyses. Key findings include a 95.9% reduction in microbial load (from 2.7×10^4 to 1.1×10^3 CFU/ml), significantly improved colour stability (mean ΔE : 2.10 vs. 6.80 in untreated controls; $F(1,18) = 284.62$, $p < 0.001$), a 5–8.3% increase in tensile strength, and improved surface morphology scores (4.30 vs. 2.10 for treated and untreated samples, respectively). Visual and tactile assessments by experienced costume professionals further confirmed superior performance in color vibrancy (9.2/10), softness (8.8/10), and ease of drape (9.0/10). The findings indicate that protease-based enzymatic finishing represents a viable, environmentally sustainable approach to preserving indigenous textiles for costume management in the Performing arts.

Keywords: Enzymatic Preservation, Aso-oke Fabric, Theatre, Film, Subtilisin Protease

representation (Onabajo, 2015). However, technical investigations into sustainable preservation strategies for maintaining the durability, hygiene, and aesthetic quality of Aso-oke in performance environments remain relatively scarce. This gap is particularly significant given the increasing demand for reusable costumes in theatre and film industries seeking cost-effective and environmentally sustainable production practices.

Among the various enzymes used in textile processing, protease enzymes Subtilisin has demonstrated effectiveness in breaking down protein-based contaminants such as sweat residues, body oils, and microbial biofilms that accumulate on frequently worn garments (Singh et al., 2022; Torres & Martinez, 2023). This study therefore investigates the application of protease enzyme (Subtilisin) in the preservation of Aso-oke fabrics used in theatre and film production. Specifically, the research evaluates the effects of enzymatic treatment on color fastness, microbial load reduction, and structural integrity of the fabric under simulated performance conditions. By integrating principles of textile science, conservation technology, and performing arts practice, the study contributes to the growing body of knowledge on sustainable costume maintenance and supports the adoption of biotechnology-based preservation methods for culturally significant textiles.

MATERIALS AND METHODS

2.1 Materials

- i. Ten varieties of Aso-oke fabric sourced from Costume room of department of Performing and film Arts, University of Ilorin, Nigeria.

- ii. Laboratory-grade protease enzyme (subtilisin) (pH 7.5–8.0).
- iii. Deionized water, nutrient agar, ethanol, and phosphate buffer solutions.
- iv. Laboratory equipment: pH meter, spectrophotometer, tensile strength tester, electron microscope, incubator, colony counter, drying oven, and weighing balance, non-ionic detergent Laboratory glass wares and containers, personal protective Equipment(PPE).

2.2 Experimental Design

The study employed a comparative experimental framework. Fabric samples were cut into standard dimensions (30x30 cm) and grouped into control (untreated) and experimental (enzyme-treated) sets. All experiments were replicated three times for statistical accuracy. Parameters analyzed included pre- and post-treatment color intensity, tensile strength, microbial colony count, and surface morphology.

2.3 Enzymatic Treatment Protocol

- i. Pre-treatment: Samples were soaked in distilled water for 15 minutes to remove loose particulates. The fabric samples were divided into two groups:

Control Group

Untreated Aso-oke samples subjected to standard washing conditions.

Experimental Group

Aso-oke samples treated with protease enzyme (Subtilisin).

Before treatment, all fabric samples were conditioned under controlled laboratory conditions at: Temperature: $21 \pm 2^\circ\text{C}$ Relative humidity: $65 \pm 2\%$ for a period of **24 hours**. This condition ensured uniform moisture content and minimized variability in experimental outcomes.

INTRODUCTION

Costume design in theatre and film serves not only as an element of visual appeal but also as a medium of character portrayal and cultural storytelling. Within a performance, costume functions as a visual language through which actor's identity, status, historical context, and mood are communicated to audience. This indicates that costume is a critical tool for communication especially cultural expression because it showcases the cultural aesthetics, artistic styles, and traditional values representative of a people (Su, 2025).

In Nigeria, one of the most iconic materials used in traditional plays and films is Aso-oke, a handwoven textile with a long-standing heritage that is emblematic of Yoruba identity. Beyond its decorative function, Aso-oke carries symbolic meanings associated with lineage, social status, and communal belonging. The fabric is widely used in weddings, coronations, and festival celebrations. The application of Aso-oke costumes in theatre and film provides the audience with a visual connection to the past while simultaneously reinforcing contemporary cultural identity. In this context, Aso-oke not only enhances visual aesthetics but also anchors character narratives in authentic cultural frameworks. Its preservation is therefore essential to ensuring continuity in the performance and appreciation of Yoruba cultural heritage. However, the unique texture and organic composition of Aso-oke, while advantageous for aesthetics and thermal comfort, present notable maintenance challenges. The fabric's dense weave structure makes it difficult to clean using conventional laundering methods, and frequent washing risks dulling vibrant

colors and weakening fibers. Prolonged storage and repeated use in theatrical environments further expose the fabric to microbial contamination, moisture accumulation, and environmental stressors. These conditions accelerate fiber deterioration and reduce the functional lifespan of costumes used in performance settings. Consequently, the preservation of such fabrics becomes not only a matter of aesthetics but also of hygiene, sustainability, occupational safety, and heritage conservation (Kumar et al., 2023).

In response to the highlighted challenges, enzymatic treatment has emerged as a promising and environmentally responsible approach to textile preservation. Recent advances in textile biotechnology indicate that enzymatic treatments can improve fabric softness, enhance dye retention, reduce microbial load, and extend textile lifespan (Chen et al., 2019; Wang et al., 2022; Patel & Natarajan, 2025). The application of enzymes in processes such as bio-polishing, desizing, and degumming has become increasingly widespread in commercial textile manufacturing. In cultural heritage conservation, enzymatic cleaning methods are now being explored for preserving historical textiles, museum artifacts, and ceremonial garments due to their precision and minimal material damage (International Council of Museums, 2023; Brown & Davies, 2024).

Despite these advancements, limited research has focused on the application of enzymatic preservation techniques to indigenous African textiles, particularly within the context of theatrical costume reuse. Existing studies on Aso-oke have primarily examined its socio-cultural significance (Adeyemi, 2011) and its role in performative arts and identity

- ii. Enzyme Activation: 1% protease solution was prepared using phosphate buffer at pH 7.5 and incubated at 37°C.
- iii. Fabric Immersion: Experimental samples were immersed in the enzyme solution for 45 minutes-60 minutes under agitation.
- iv. Rinsing: Treated samples were rinsed thoroughly three times in deionized water and allowed to air-dry for 24 hours. While the control samples underwent identical washing conditions without the addition of the enzyme to ensure consistency in experimental comparison.

2.4 Analytical Procedures

- i. Color Fastness: Measured using a Datascolor spectrophotometer. ΔE values were calculated pre- and post-treatment to determine the color retention of fabric dyes through washing and friction.
- ii. Tensile Strength: Evaluated using an Instron tensile tester, following ASTM D5035 standards.
- iii. SEM Analysis: Surface morphology was observed using a Scanning Electron Microscope at 2000x magnification to observe changes in fiber morphology before and after treatment
- iv. Microbial Load: Bacterial colonies were cultured on nutrient agar plates and counted using a digital colony counter. Microbial reduction was calculated by comparing the

microbial counts of treated samples with those of untreated control samples.

- v. Visual and Tactile Assessments: Conducted by a panel of five experienced costume designers using a standardized rubric assessing texture, vibrancy, and pliability.

vi. Statistical Analysis: All data were subjected to descriptive analysis with mean difference separated using one-way Analysis of Variance (ANOVA) with Tukey's HSD

RESULTS

The results from the experimental study demonstrated measurable improvements across all assessed parameters after protease enzyme treatment of Aso-oke fabric.

3.1 Colour Fastness

The colour fastness tests indicated significant retention of colour intensity in enzyme-treated samples. Treated fabrics showed an average ΔE (colour difference) of 2.1 compared to 6.8 in untreated controls after simulated washing and exposure to artificial stage lighting. This low ΔE value in treated samples signifies minimal perceptible colour change.

One-way ANOVA revealed a statistically significant effect of enzymatic treatment on colour retention, $F(1, 18) = 284.62$, $p < 0.001$. As shown in Table 3.1, enzyme-treated samples maintained a mean colour difference (ΔE) of 2.10 ± 0.45 , compared to 6.80 ± 0.72 in untreated controls. Tukey's HSD post hoc analysis confirmed a statistically significant mean difference of 4.70 between the two groups ($p < 0.001$), indicating that enzyme-treated samples exhibited substantially better colour stability than untreated controls following simulated washing and artificial stage lighting exposure.

measurable increase in breaking force among enzyme-treated Aso-oke fabric samples compared to untreated controls. Treated samples demonstrated a 5–8% improvement in tensile strength, indicating enhanced fiber cohesion and resistance to mechanical stress following enzymatic treatment. –To determine whether the observed differences in tensile strength were statistically significant across treatment conditions, a one-way Analysis of Variance (ANOVA) was conducted, followed by Tukey's Honestly Significant Difference (HSD) post hoc test for pairwise comparisons.

3.2 Tensile Strength

Tensile strength testing revealed a

Table 3.2: Consolidated Descriptive Statistics, ANOVA, and Tukey HSD Analysis for Tensile Strength (N) of Asooke Fabric

Section	n	Mean (N)	SD	Increase	SS	df	MS	F	P-value
A. Descriptive Statistics									
Untreated (Control)	10.00	220.40	6.50						
Enzyme Treated(Low)	10.00	232.10	5.80	0.05					
Enzyme Treated (High)	10.00	238.60	6.10	0.08					
B. One-way ANOVA									
Between Groups					1842.35	2.00	921.18	18.47	< 0.001
Within Groups					1347.62	27.00	49.91		
Total					3189.97	29.00			
C. Tukey HSD Post Hoc									
	Comparison	Mean Diff.	Std. Error	Significance					
	Control vs. Low	11.70	3.16	$p = 0.004$					
	Control vs. High	18.20	3.16	$p < 0.001$					
	Low vs. High	6.50	3.16	$p = 0.041$					

A one-way ANOVA confirmed statistically significant differences in tensile strength across treatment conditions, $F(2, 27) = 18.47$, $p < 0.001$. The low-concentration enzyme-treated group demonstrated a 5.3% increase in breaking force (232.1 N) relative to the untreated control (220.4 N), while the high-concentration group achieved an 8.3% increase (238.6 N). Tukey's HSD post hoc test confirmed that both treatment levels significantly outperformed the control ($p = 0.004$ and $p < 0.001$, respectively), and the high-concentration group was statistically superior to the low-concentration group (Mean Diff = 6.50, $p = 0.041$), indicating a dose-dependent response.

3.3 Surface Morphology (SEM Analysis)

SEM imaging confirmed that treated fabrics exhibited a visibly smoother, more uniform fiber structure with significantly fewer micro-debris and contaminants. Prior to treatment, fibers appeared clustered with uneven textures and visible particulate matter, while post-treatment images

revealed aligned yarns and cleaner fiber strands. This improvement in surface morphology enhances the tactile feel and presentation of the fabric. Scanning Electron Microscopy (SEM) imaging confirmed that enzyme-treated Aso-oke fabrics exhibited a visibly smoother and more uniform fiber structure with significantly fewer micro-debris and contaminants compared to untreated samples. Prior to treatment, fibers appeared clustered with uneven textures and visible particulate matter, indicating surface contamination and structural irregularities. In contrast, post-treatment images revealed aligned yarns and cleaner fiber strands, suggesting improved surface condition and reduced material degradation. To quantitatively evaluate differences in surface morphology among treatment groups, a **one-way Analysis of Variance (ANOVA)** was conducted using surface morphology scores derived from SEM image analysis. A **Tukey's Honestly Significant Difference (HSD) post hoc test** was subsequently applied to determine

Table 3.3: Consolidated Descriptive Statistics, ANOVA, and Tukey HSD Analysis for Surface Morphology Scores of Asooke Fabric

Section	n	Mean Score	SD	SS	df	MS	F	P-value
A. Descriptive Statistics								
Untreated (Control)	10.00	2.10	0.42					
Enzyme Treated (Low)	10.00	3.65	0.38					
Enzyme Treated (High)	10.00	4.30	0.36					
B. One-way ANOVA								
Between Groups				24.68	2.00	12.34	56.92	< 0.001
Within Groups				5.85	27.00	0.22		
Total				30.53	29.00			
C. Tukey HSD Post Hoc								
	Comparison	Mean Diff.	Std. Error	Significance				
	Control vs. Low	1.55	0.21	$p < 0.001$				
	Control vs. High	2.20	0.21	$p < 0.001$				
	Low vs. High	0.65	0.21	$p = 0.012$				

SEM analysis revealed significant differences in surface morphology scores across treatment groups, $F(2, 27) = 56.92$, $p < 0.001$. Untreated control samples scored a mean of 2.10 ± 0.42 on the surface morphology scale, reflecting clustered, irregular fibre surfaces with visible particulate matter. The low-concentration enzyme-treated group achieved a mean score of 3.65 ± 0.38 , while the high-concentration group attained a mean of 4.30 ± 0.36 . Tukey's HSD post hoc analysis confirmed that all pairwise comparisons were statistically significant: Control vs. Low (Mean Diff = 1.55, $p < 0.001$), Control vs. High (Mean Diff = 2.20, $p < 0.001$), and Low vs. High (Mean Diff = 0.65, $p = 0.012$), indicating a concentration-dependent improvement in surface morphology.

3.4 Microbial Load Reduction

Microbial analysis demonstrated a substantial reduction in colony-forming units (CFUs) following enzymatic treatment of Aso-oke fabric. Initial microbial readings averaged 2.7×10^4 CFU/ml, which decreased to 1.1×10^3 CFU/ml after treatment, representing a microbial reduction of over 95%. —To determine whether the observed reduction in microbial load was statistically significant across treatment conditions, a one-way ANOVA was performed, followed by Tukey's HSD post hoc test.

Table 3.4: Consolidated One-way ANOVA and Tukey HSD Analysis for Microbial Load Reduction (CFU/ml) in Asooke Fabric

Section	n	Mean CFU/ml	% Reduction	SS	df	MS	F	P-value
A. Descriptive Statistics								
Untreated (Control)	10	2.70×10^4						
Control Wash Only	10	2.90×10^3	89.30%					
Posttreatment (Enzyme)	10	1.10×10^3	95.90%					
B. One-way ANOVA								
Between Groups				6.42×10^8	2	3.21×10^8	74.6	< 0.001
Within Groups				1.16×10^8	27	4.30×10^6		
Total				7.58×10^8	29			
C. Tukey HSD Post Hoc								
	Comparison	Mean Diff.	Std. Error	Significance				
	Untreated vs. Post	2.59×10^4	1.12×10^3	$p < 0.001$				
	Untreated vs. Wash	2.41×10^4	1.12×10^3	$p < 0.001$				
	Wash vs. Post	1.80×10^3	1.12×10^3	$p = 0.021$				

One-way ANOVA confirmed that differences in microbial load across the three conditions were statistically significant, $F(2, 27) = 74.56$, $p < 0.001$. Untreated samples recorded a mean of 2.7×10^4 CFU/ml, while the wash-only control reduced the count to 2.9×10^3 CFU/ml (89.3% reduction). The enzyme-treated group achieved the greatest reduction to 1.1×10^3 CFU/ml (95.9% reduction). Tukey's HSD post hoc analysis confirmed that the enzymatic treatment was statistically superior to washing alone (Mean Diff = 1.80×10^3 , $p = 0.021$), as well as to the untreated control ($p < 0.001$).

3.5 Visual and Tactile Assessment

A panel of five experienced costumiers evaluated the aesthetic and functional

performance of enzyme-treated and untreated Aso-oke fabrics using a structured rating scale. The treated fabrics received higher scores across all assessment categories, including color vibrancy (mean score of **9.2/10**), softness (**8.8/10**), and ease of drape (**9.0/10**). In comparison, untreated fabrics received comparatively lower ratings, reflecting diminished visual appeal and tactile comfort following repeated usage cycles. To determine whether differences in visual and tactile performance among treatment conditions were statistically significant, a **one-way Analysis of Variance (ANOVA)** was conducted. A **Tukey's Honestly Significant Difference (HSD) post hoc test** was subsequently applied to identify specific differences between groups.

Table 3.5: Consolidated Visual and Tactile Assessment: Descriptive Statistics, ANOVA, and Tukey HSD Analysis

Section	n	Colour Vibrancy	Softness	Ease of Drape	Overall Mean	F	p-value
A. Descriptive Statistics							
Untreated	5.00	6.80	6.50	6.70	6.70		
Standard Wash	5.00	7.90	7.60	7.80	7.80		
Enzyme Treated	5.00	9.20	8.80	9.00	9.00		
B. One-way ANOVA			SS		df	MS	
Between Groups			28.64		2.00	14.32	
Within Groups			12.98		18.00	0.72	
C. Tukey HSD Post Hoc							
	Comparison			Mean Diff.		Std. Error	p-value
	Untreated vs. Treated			2.35		0.41	< 0.001
	Untreated vs. Wash			1.48		0.41	0.01
	Wash vs. Treated			0.87		0.41	0.03

One-way ANOVA confirmed statistically significant differences across treatment groups in all sensory parameters evaluated, $F(2, 18) = 19.85$, $p < 0.001$. The enzyme-treated group achieved the highest overall mean score of 9.0/10, compared to 7.8/10 for the wash-only group and 6.7/10 for untreated controls. Tukey's HSD post hoc analysis revealed that the enzyme-treated group significantly outperformed both the untreated control (Mean Diff = 2.35, $p < 0.001$) and the wash-only group (Mean Diff = 0.87, $p = 0.032$). The wash-only group also significantly outperformed the untreated control (Mean Diff = 1.48, $p = 0.010$).

DISCUSSION

The results of this study demonstrate that protease enzyme (Subtilisin) treatment substantially improves the colour stability, structural integrity, microbial hygiene, and sensory properties of Aso-oke fabric used in theatre and film costuming. The significantly improved colour fastness in enzyme-treated samples (mean ΔE : 2.10) relative to untreated controls (ΔE : 6.80) is consistent with findings reported by Wang et al. (2022), who demonstrated that protease-mediated bio-polishing significantly enhanced colour retention in protein-based and blended fabrics by removing surface microfibrils that cause diffuse light scattering and dye bond instability. Similarly, Patel and Natarajan (2025) reported that enzymatic finishing reduced colour change (ΔE) values by up to 60% relative to conventional washing treatments in synthetic and natural fibre blends. The present findings extend these results to a culturally significant handwoven indigenous textile and

demonstrate their applicability within a performance context, where lighting intensity and costume reuse cycles create particularly demanding conditions for colour stability.

The 5–8.3% increase in tensile strength observed in enzyme-treated samples aligns with prior reports that enzymatic removal of protein-based biofilms and residues from fabric surfaces reduces inter-fibre friction and thereby preserves yarn structural cohesion (Chen et al., 2019). Singh et al. (2022) similarly reported that protease enzyme treatment of protein-based fabric contaminants was associated with enhanced mechanical performance in textiles subjected to repeated use cycles. These findings collectively indicate that enzymatic treatment not only preserves colour vibrancy but also actively maintains the mechanical resilience of the fabric, which is critical in performance environments where costumes are subjected to repeated motion, stretching, and physical stress. The SEM data, showing a shift in surface morphology score from 2.10 to 4.30 following high-concentration treatment, provide direct visual and quantitative evidence of the fibre-level changes that underpin these improvements in both strength and sensory quality.

The 95.9% reduction in microbial load achieved by the protease treatment represents a clinically and practically relevant level of decontamination for shared performance costumes. Torres and Martinez (2023) reported comparable antimicrobial outcomes using enzyme-based cleaning systems for reusable textiles in performance settings, attributing the reduction to the proteolytic degradation of organic substrates including sweat residues,

skin cells, and lipid deposits that serve as growth substrates for bacterial colonisation. The present findings are consistent with these observations and extend them to an African indigenous textile context. In theatre environments where costume sharing among performers is routine, this level of microbial reduction is of direct relevance to occupational health, as microbial contamination of shared garments has been linked to skin irritation, odour formation, and allergenic responses (Ogunbanwo & Ilesanmi, 2018; Garcia et al., 2022).

From a sustainability perspective, the use of protease enzymes under mild aqueous conditions (pH 7.5, 37°C) offers a more environmentally responsible alternative to conventional chlorine-based or solvent-based cleaning agents, which have been associated with fibre degradation, dye fading, and aquatic pollution (Zhang et al., 2024; European Environment Agency, 2022). The adoption of enzyme-based preservation methods is therefore consistent with broader sustainability goals in the textile and creative industries. Moreover, extending the functional lifespan of culturally significant fabrics such as Aso-oke through sustainable preservation methods contributes to heritage conservation objectives identified by international frameworks (UNESCO, 2022; Ahmed & Hassan, 2022). The convergent evidence from objective laboratory analyses and practitioner evaluations in this study provides a comprehensive validation of enzymatic preservation as both a scientific and an industry-relevant strategy for indigenous textile maintenance in the performing arts.

CONCLUSION

This study demonstrates that protease enzyme (Subtilisin) treatment represents a scientifically validated and practically viable approach to preserving Aso-oke fabrics for use in theatre and film productions. Significant improvements were recorded across all assessed parameters: a 95.9% reduction in microbial load, a 5–8.3% increase in tensile strength, substantially improved colour stability (ΔE : 2.10 vs. 6.80), enhanced surface morphology scores (4.30 vs. 2.10), and superior sensory performance ratings by experienced costume practitioners. These findings confirm that enzymatic treatment can maintain the aesthetic quality, structural resilience, and hygienic safety of culturally significant indigenous fabrics without compromising their cultural authenticity or material integrity.

It is recommended that theatre companies and film production houses adopt enzyme-based textile treatments as a standard protocol for costume maintenance and preservation, particularly for shared and repeatedly worn indigenous garments. Future studies should investigate long-term preservation outcomes over extended storage periods, explore multi-enzyme systems combining proteases with cellulases or lipases to address a broader range of contaminants, and examine the economic feasibility of large-scale implementation within African creative industry contexts. Community-based pilot programmes involving local weavers and theatre practitioners would further support the translation of these findings into practice.

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[CORRECTED REFERENCE LIST — Duplicates removed; all entries in APA 7th edition format. Deleted entries shown in red strikethrough; additions/corrections shown in green.]

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