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Research Article

Antimicrobial Finish for Cotton/polyester from Natural Bio-extracts

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Abstract: This study develops and applies sustainable antimicrobial finishes derived from *Azadirachta indica* (Neem), *Butea monosperma,* and *Litchi chinensis* leaf extracts to 50/50 cotton/polyester blend fabrics. The antimicrobial efficacy of these finishes was evaluated, revealing a 100% reduction in microbial growth after 22 hours and six days. Before and after applying antimicrobial finish FTIR, SEM and fabric aesthetic properties were checked. The antimicrobial finish was applied by the pad dry cure method and finish was fixed by using of polyurethane binder. In case of aesthetic properties (stiffness, smoothness appearance) antimicrobial finish had positive effect on 50/50 cotton/polyester. The treated fabrics also exhibited significant increases in stiffness ($p < 0.001$, $\eta^2 = 0.85$). Additionally, the smoothness appearance of treated fabrics was assessed, revealing a slight decrease in smoothness appearance ratings as compared to untreated controls group, although this decrease was not statistically significant ($p = 0.29$). Fourier Transform Infrared (FTIR) spectroscopy revealed changes in functional groups, indicating successful finish application. Scanning Electron Microscopy (SEM) micrographs displayed surface modifications and filament breakage. The results were analyzed through ANOVA. The fabric properties were checked by using AATCC standard test methods. These eco-friendly finishes offer promising alternatives to synthetic antimicrobials, enhancing textile sustainability and consumer safety. The findings of this study contribute to the development of sustainable and environmentally friendly textile finishes.

Keywords: Antimicrobial, Natural Extracts, Aesthetic Properties *A. indica*, *L. chinensis*, *B. monosperma*, Smoothness and Surface Appearance.

1. INTRODUCTION

Regular polymers with a plant-based (vegetable) origin have a position with materials. People have been using it for hundreds of years with the sole purpose of insuring (bodies) and covering (temperature, dust, daylight, wind, and so on). Additionally, clothing has played a vital role in human existence and has become essential with the advancement of trend-setting technologies. Among specialised materials, clinical materials are a very promising field that is directly related to human prosperity and well-being. It includes resources used by wards, paramedical staff, specialists, attendants, and pre- and post-employable tasks [1, 2]. There are bacterial or other harmful germs everywhere in our surroundings that can harm or benefit humans. The epidermis, nasal passages, stomach, and other areas of the human body are home to a variety of bacterial species [3, 4]. Antimicrobial additions to materials can protect the human body from harmful germs. Microorganisms are too small for the human unaided eye to see. Microbes, growths, diseases, and green growth are all considered microorganisms [5]. Neem or *Azadirachta indica*, is widely distributed over the Indian subcontinent and belongs to the *Meliaceae* (Mahogony) family. It is one of the plants with the most elaborate naturally occurring mixes. Because of its antibacterial and healing qualities, neem has been used in traditional Indian medicine for hundreds of years. Neem has been demonstrated to be less toxic to warm-blooded animals, such as humans. Neem subordinates have been used in

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toothpastes, cosmetics, toiletries, and home-grown medications due to the plant's exceptional qualities [6, 7]. *B. monosperma* leaves have shown useful in treating diabetes, glycosuria, and skin conditions. It has demonstrated impressive results in eliminating tapeworms and roundworms. The antibacterial activity of *B. monosperma* has been investigated by El-Shafei *et al*. [8]. *Litchi chinensis* (Lychee) is an evergreen, soapberry tree within the *Sapindaceae* family. The results of the litchi organic product, for example, blossoms, pericarp, and seeds have shown anti-oxidative properties [9-11].

The textile industry's reliance on synthetic antimicrobial agent's poses environmental and health risks. Developing sustainable, eco-friendly alternatives that maintain fabric aesthetic properties is crucial. This study aims to create effective, plant-based antimicrobial finishes balancing efficacy, aesthetics, and environmental sustainability. Existing literature highlights the potential of plant-based antimicrobial agents as eco-friendly alternatives to synthetic chemicals. However, limited studies have investigated the application of these agents on cotton/polyester blend fabrics. By investigating the effects of *A. indica, B. monosperma,* and *L. chinensis* extracts on fabric properties, this research contributes to the development of sustainable textile finishes. The primary objective of this study is to develop and evaluate sustainable antimicrobial finishes derived from natural plant extracts, specifically *Azadirachta indica* (Neem), *Blepharis monosperma,* and *Litchi chinensis*, for application on 50/50 cotton/polyester blend fabrics. This research aims to address the growing concern of antimicrobial resistance and environmental pollution caused by synthetic antimicrobial agents in the textile industry.

2. MATERIALS AND METHODS

In this study antimicrobial finish was extracted from three plants leaves, i.e., *A. indica, B. monosperma* and *L. chinensis* and applied on 50/50 cotton/polyester, 50% concentration solution was used. The fabric samples were cut, treated with antimicrobial finish and then tested to govern their effectiveness as antimicrobial fabrics. Antimicrobial agents were extracted from leaves of *A. indica*, *B. monosperma* and *L. chinensis*. Extractions of antimicrobial agents from plants were carried out in laboratory of Botany Department, Government College University, Lahore. Antimicrobial finish was applied in National Textile University (NTU) Faisalabad. Binder was used to improve the durability of finish. Antimicrobial testing was carried out in Centre of Excellence in Molecular Biology (CEMB). To check the presence of antimicrobial finish on fabrics pre-test post-test, FTIR test was conducted at the Institute of Chemistry, University of the Punjab, SEM test was conducted in The Centre for Solid State Physics, University of the Punjab, Lahore. Fabric properties were rechecked after applying antimicrobial finish whether it affected the fabric properties or not. This part of experiment was conducted in National Textile University, Faisalabad.

2.1. Sample Preparation

Samples of fabrics 50/50 cotton/polyester were taken from fabric trader of Faisalabad. Its quality was authenticated by the study co-supervisor at NTU Faisalabad. Sample size was five yards which depended upon the checking fabric properties and tests. Unfinished fabric was taken and these were bleached at NTU. Untreated fabric was taken as control group and the presence of microorganisms was checked in CEMB. The fabric consists on plain weave with 217 GSM.

2.2. Fabric Preparation

After purchasing the fabric 50/50 cotton/polyester was first de-sized. In de-sizing enzyme Bactasal HTN was used in ratio of 1g/litre. The pH was 5-6 and temperature was 60-70 °C. The cotton/polyester fabric was dipped in solution for 45 minutes. After de-sizing, scouring was done by using NaOH 4g/l and wetting agent 2g/l, detergent was used in the ratio of 1 g/l at 90 °C, temperature was maintained during the process. The cotton/polyester fabric was treated for 1 hour. In bleaching of cotton/polyester took H_2O_2 5g/l, NaOH (pH 10-10.5) 2g/l, stabilizer 2g/l and requesting agent 2g/l. The temperature of the process was 90 °C. The fabric was treated in this solution for one hour.

2.3. Development of Finish

The leaves of *A. indica* (Neem), *B. monosperma* and *L. chinensis* were collected from the botanical garden of Government College University, Lahore. The plant leaves of *A. indica*, *B. monosperma* and

L. chinensis were identified and authenticated. The leaves were washed and then dried for two months under shadow. These were grinded by using a stainless-steel grinder into very fine powder. This powder was stored in air tight, high density poly ethylene vessels before extraction. The weights of dry powder of leaves *A. indica* (Neem), *B. monosperma* and *L. chinensis* were 500 g each. The ratio of grinded leaves and distilled water was 100 g/250 ml. This process was repeated for *B. monosperma* and *L. chinensis*. This soaked material was left for 7 days and stirred it twice a day. After that it was filtered by using muslin cloth then filtered again by using Whatman filter paper. The filtered extracts of *A. indica (*Neem), *B. monosperma* and *L. chinensis* were concentrated by a rotary film evaporator.

2.4. Application of Finish

200 milliliters of *A. indica* (neem) leaf extract, 50 milliliters of polyurethane binder, and 150 milliliters of distilled water were combined to create the diluted concentration of finish. For *B. monosperma* and *L. chinensis,* the same ratio was applied. The pad dry cure machine at NTU was used to apply the antimicrobial finish. The pad dry cure machine (method) was used for two minutes of drying and three minutes of curing at 120 °C and 150 °C, respectively.

2.5. Washing

To confirm that the fabric samples had been cleaned, eco-friendly laundry was performed at home using AATCC test method 135-2003. The following tools were used:

- A washing machine that operates automatically.
- A tumble dryer that operates automatically.
- Features for line and drip drying, the 1993 AATCC standard reference detergent was use.

2.6. Antimicrobial Test

The bacteria under investigation were those discovered during the experiment. Microbes, both Gram-positive and Gram-negative, were examined. These bacteria were studied in CEMB under normal conditions. For textile testing, the usual conditions are 20 ± 2 °C and 65 ± 2% relative humidity.

2.7. Aesthetic Properties

2.7.1. Stiffness

For the stiffness test, the Shirley stiffness tester was used. A fabric strip was cut that was a 6 × 1-inch sample on Shirley stiffness tester underneath the template. Both were slowly pushed forward. The fabric strip was dropped over the edge of the stiffness tester platform by the movement of the template. The sample was continued until the tip of sample as saw in mirror cut both index lines. The bending length noted from the scale. Each sample was tested four times at each end and reading was taken by strip turned over. Mean value both warp and weft were calculated.

2.7.2. Smoothness appearance

The 1993 AATCC Standard Reference technique was applied for the surface appearance test using an automated washing machine. The three-dimensional replicas depicted in Figure 1 were compared to the treated samples. The surface appearance as an aesthetic property was checked by using AATCC Technical Manual /2004 TM 124-2001 203 test method. The surface appearance was measured by evaluating the smoothness appearance of surface of plane fabric sample. Three samples were cut from fabric 15 inches square. Surface appearance was checked after five home laundries. After machine washing the fabric samples were evaluated by using standard replica in standard.
The fabric samples were observed by three trained observers by using standard replicas and rate independently. In room all lights turned off, the overhead bright light was the only way of light

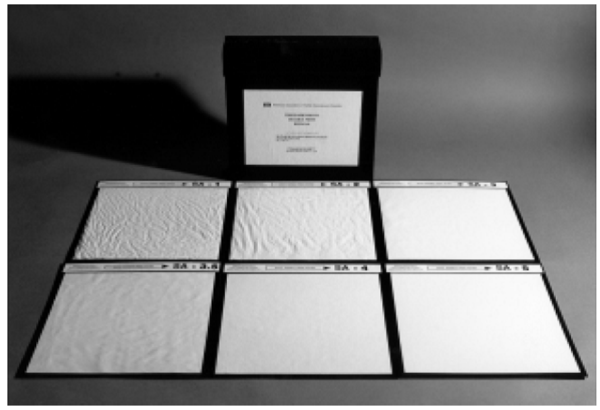

Fig. 1. AATCC 3-D smoothness appearance replicas.

source. The trained observer was standing four feet away from the board on which testing samples and standard replicas were mounted on each side of testing sample to enable comparative evaluation. Then assign the number which present on most nearly match the finished appearance. The detail of smoothness appearance replicas is as under.

- SA-4 Replica. Smooth, finished appearance.
- SA-3 Replica. Mussed, no pressed appearance.
- SA-2 Replica. Rumpled, obviously wrinkled appearance.
- SA-1 Replica. Crumpled, creased and severely wrinkled appearance.

2.8. Sustainability in Home Laundry

Cut the sample from fabric in standard testing atmosphere. Samples were placed on the flat surface. Automatic washing machine did laundry by the following steps as washing, rinsing, and drying. In washing, automatic washing machine weights the fabric samples. According to sample size water level was selected. The temperature for washing and rinsing was less than 29 °C. Add 1993 AATCC standard reference detergent by the ratio of 1g/l. Add fabric samples to washing machine, set the washer cycle and time. After that rinsed and dried the samples then line dry the samples. In line dry, hung each sample in vertical direction by clipping it two corners. The fabric samples were dried at room temperature, below 26 °C.

2.9. Scanning Electron Microscopy (SEM)

Sample Preparation: Treated and untreated fabric samples were cut into 1 cm × 1 cm pieces and mounted on aluminium stubs using double-sided adhesive tape.

- Coating: Samples were sputter-coated with a thin layer of gold (10 nm) to enhance conductivity and prevent charging.
- Microscopy: A scanning electron microscope (SEM) (Model: JEOL JSM-6610LV) was used to examine fabric surfaces.
- Operating Conditions: Accelerating voltage: 15 kV; working distance: 10 mm; magnification: 500X and 1000X.
- Image Analysis: SEM images were analysed using Image software to assess surface modifications and filament breakage.

2.10. Fourier Transform Infrared (FTIR)

Sample Preparation: Treated and untreated fabric samples were cut into small pieces and mixed with potassium bromide (KBr) powder.

- Pellet Formation: The mixture was pressed into a transparent pellet using a hydraulic press.
- Spectroscopy: A Fourier Transform Infrared (FTIR) spectrometer (Model: Shimadzu IRTracer-100) was used to analyse fabric chemical composition.
- Operating Conditions: Scan range: 4000-400 cm^{-1}; resolution: 4 cm^{-1}; number of scans: 32.
- Spectral Analysis: FTIR spectra were analyzed using Shimadzu IR Solution software to identify functional groups and peak shifts.

3. RESULTS

3.1. Effect on Aesthetic Property

The results of aesthetic properties (stiffness, smoothness appearance) on treated and untreated cotton/polyester fabric with *A. indica, B. monosperma* and *L. chinensis* are presented in Table 1. Table 1 presents the results of Pillai's test, which indicates a significant difference ($p = 0.000$) in the effect of antimicrobial finishes on the stiffness (warp, weft) and smoothness appearance of cotton/polyester fabric. The effect size was large ($\eta^2 = 0.995$). To further investigate the differences, ANOVA was applied to compare the effects of *A. indica*, *B. monosperma*, *L. chinensis*, and the control group on stiffness (warp, weft) and smoothness appearance. The F-test results show a significant difference ($p = 0.001$) in the effect of antimicrobial finishes on stiffness (warp) of cotton/polyester fabric, with a large effect size ($\eta^2 = 0.85$).

Table 1. Effect of antimicrobial finish on stiffness and smoothness appearance of cotton/polyester fabric.

	Plants		
	F	P	η^2
Multivariate	72.32	0.000	0.995
Univariate			
Stiffness Wrap (cm)	151.19	0.001	0.85
Stiffness weft (cm)	2.4	0.143	0.47
Stiffness warp+ weft (cm)	9.941	0.001	0.651
Smoothness Appearance	1.50	0.29	0.36

However, no significant differences were found in the effects of antimicrobial finishes on stiffness (weft) and smoothness appearance. Additionally, the F-test results indicate a significant difference in the effect of antimicrobial finishes on combined stiffness (warp + weft) of cotton/polyester fabric, with a large effect size ($\eta^2 = 0.651$).

Table 2 shows that *A. indica and B. monosperma* and *L. chinensis* plant leaves extracts antimicrobial finish have effect on stiffness warp of cotton/polyester fabric as compared to control group. One-way ANOVA showed that the difference in antimicrobial finish between control group (M = 3.84, SD = 0.31), the first experimental group *A. indica* (M = 4.65, SD = 0.43), second experimental group *B. monosperma* (M = 4.54, SD = 0.32) and third experimental group *L. chinensis* (M = 4.38, SD = 0.20) were statistically significant (F = 151.19, p = 0.001, $\eta^2 = 0.85$). Results revealed that control group scored significantly lower than the experimental groups. However, the three experimental groups' *A. indica*, *B. monosperma* and *L. chinensis* antimicrobial finish significantly affects the stiffness warp. The significant difference between control group and the first, second and third (*A. indica*, *B. monosperma*, *L. chinensis*) experimental group is also evident from the big difference in the mean values and remarkable difference in standard deviation (control = 0.31, *A. indica* = 0.43, *B. monosperma* = 0.32, and *L. chinensis* = 0.20). When we compare the stiffness (warp) of cotton/polyester fabric treated with antimicrobial finishes from different plant extracts (*A. indica*, *B. monosperma*, and *L. chinensis*) to the control group. The results show that all treated groups have significantly higher stiffness (warp) values than the control group. Table 2 shows that *A. indica*, *B. monosperma* and *L. chinensis* plant leaves extracts antimicrobial finish have effect on stiffness (warp + weft) of cotton/polyester fabric as compared to control group. One-way ANOVA showed that the difference in antimicrobial finish between control group (M = 3.54, SD = 0.24), the first experimental group *A. indica* (M = 4.00, SD = 0.37), second experimental group *B. monosperma* (M = 4.01, SD = 0.27) and third experimental group *L. chinensis* (M = 3.97, SD = 0.35) were statistically significant (F = 9.94.19, p = 0.001, $\eta^2 = 0.651$). Results revealed that control group scored significantly lower than the experimental groups. However, the three experimental groups' *A. indica*, *B. monosperma* and *L. chinensis* antimicrobial finish significantly affects the stiffness warp. The significant difference between control group and the first, second and third (*A. indica*, *B. monosperma*, *L. chinensis*) experimental group is also evident from the big difference in the mean values and remarkable difference in standard deviation (control = 0.24, *A. indica* = 0.37, *B. monosperma* = 0.27, *L. chinensis* = 0.35). The reason was that antimicrobial finish made a coating on treated fabric which increases the stiffness of antimicrobial treated fabric as compare to untreated fabric. So, this finish significantly affects the aesthetic properties (stiffness, smoothness appearance) of cotton/polyester fabric.

The results of microorganisms' reduction on treated and untreated cotton/polyester fabric with *A. indica, B. monosperma* and *L. chinensis* are presented in Table 3. From Table 3 it is observed that after 22 hours there were no microorganisms' growth shown while after six days microorganisms growth has shown on untreated fabric. The treated fabrics show 100% reduction on all samples after 22 hours, after six days there was no microorganisms shown treated fabric while five microorganisms shown on untreated cotton/polyester sample.

The cotton-polyester blend fabric IR spectrum given in Figure 2 shows that a broad peak at 1730

Table 2. Effect of antimicrobial finish on stiffness of cotton/polyester fabric.

	Control Group		***A. indica***		***B. monosperma***		***L. chinensis***	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Stiffness warp (cm)	3.84	0.31	4.65	0.43	4.54	0.32	4.38	0.20
Stiffness weft (cm)	3.24	0.18	3.28	0.33	3.48	0.23	3.56	0.53
Stiffness warp + weft (cm)	3.54	0.24	4.00	0.37	4.01	0.27	3.97	0.35
Smoothness Appearance (SA Replica)	3.50	0.50	3.00	0.00	3.00	0.50	3.00	0.00

Table 3. Quantitative analysis test results of treated and untreated cotton/polyester sample.

	Untreated	*A. indica*	*B. monosperma*	*L. chinensis*	Reduction %
Readings after 22 hours					
1st reading	0	0	0	0	100%
2nd reading	0	0	0	0	100%
3rd reading	0	0	0	0	100%
Readings after 6 days					
1st reading	2	0	0	0	100%
2nd reading	1	0	0	0	100%
3rd reading	2	0	0	0	100%

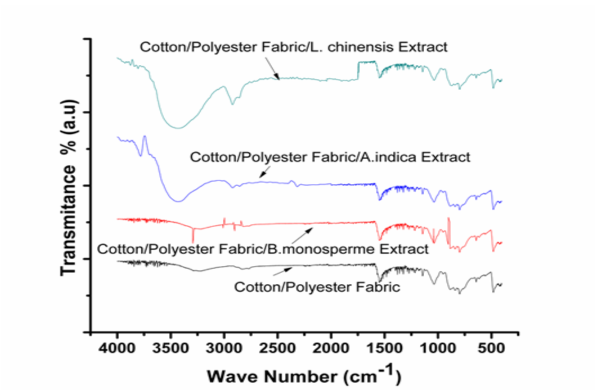

Fig. 2. FTIR Spectra of untreated vs treated cotton/polyester blend fabrics.

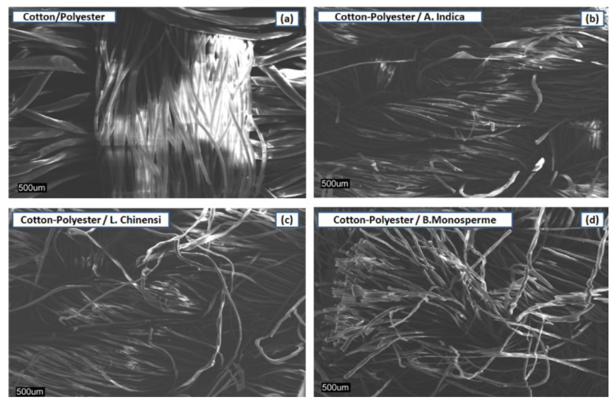

Fig. 3. SEM micrographs of untreated and treated cotton-polyester fabric.

cm^{-1} is characteristic of carbonyl stretching of unsaturated ester. The width of the peak reduced and the peak value has been shifted to higher wave number, that is, 1750 cm^{-1}. A small peak in the region between 800 and 850 cm^{-1} can be accounted for out-of-plane bending of aromatic ring system. The peak at 1250 cm^{-1} and 1300 cm^{-1} may be due to C-O stretching of the polymer back bone. An intense peak at 2350–2360 cm^{-1} can be attributed to methylene C–H stretching [14]. The small peak close to 3000 cm^{-1} can be correlated to C-H stretching of aromatic ring. An interesting feature in the above-discussed spectrum was that an additional sharp small peak observed at around 3600 cm^{-1} corresponds to free -OH groups of cellulose components indicating that solvent treatment had increased the extent of amorphous region in the cotton component of the material. The observed small peaks between the regions 1110–1150 cm^{-1} were due to cellulosic component of the fiber materials.

Figure 3 portrayed the outcome of treatment of extract on cotton/polyester fabric. Figure 3(a) is the SEM image of untreated cotton/polyester fabric. The fabric appears to have a smooth and compact structure with tightly packed fibers. The fibers are predominantly linear and parallel, suggesting minimal surface modification or additional treatment. This is likely the control sample, showing the baseline morphology of untreated Cotton/Polyester. Figure 3(b) shows the results of fabric that was treated with *A. indica*, these results indicate that the surface of the fabric shows increased roughness compared to the control. Fibers seem less aligned and have a scattered appearance, suggesting that *Azadirachta indica* (Neem) extract or treatment caused some disruption in the fiber arrangement. This change might indicate that the extract influenced the fabric's surface, potentially due to deposition or chemical interactions. Figure 3(c) shows SEM results of fabric treated with *L. chinensis* these results show that the morphology is marked by the presence of loosely aligned fibers with visible branching and irregular patterns. *Litchi chinensis* treatment seems to have further altered the fiber structure, potentially increasing porosity or roughness. This could indicate that the treatment affected the fiber bonds or introduced new surface features, enhancing texture. Figure 3(d) shows that when fabric was treated with *B. monosperma* the fibers display the most disrupted and entangled appearance among the samples. The *Butea monosperma* treatment likely caused significant modifications, leading to a highly irregular surface structure. The increased roughness and random alignment suggest a stronger interaction between the treatment and the fabric, which may impact properties like absorption, texture, or durability. The treated cotton/polyester fabric shows presence of finish as compare to untreated fabric. The untreated cotton/polyester fabric exhibits a smooth surface, whereas the treated samples display increasing roughness. Moreover, the fiber arrangement in the untreated sample is characterized by parallel and compact fibers, whereas the treated samples show progressively more disordered and entangled structures. Notably, each treatment, namely *Azadirachta*, *Litchi*, and *Butea*, has distinct effects on the fabric, with *Butea monosperma* causing the most significant disruption. These structural changes can have a profound impact on the physical, chemical, and mechanical properties of the fabric, including breathability, durability, hydrophilicity, and antimicrobial activity, depending on the purpose of the treatments.

4. DISCUSSION

In this study the antimicrobial finish derived from plant extracts impacts fabric aesthetic properties due to physical and chemical changes. The deposition of extract particles onto the fabric surface alters its texture and smoothness, while interactions between extract compounds and fiber molecules affect stiffness and flexibility. Fourier Transform Infrared (FTIR) spectroscopy reveals corresponding material structure changes, including modifications to functional groups and hydrogen bonding. Specifically, shifts in carbonyl stretching (1730 cm^{-1}) indicate interactions between extract compounds and fiber ester groups, influencing stiffness, and changes in hydroxyl stretching (3600 cm^{-1}) suggest hydrogen bonding between extract compounds and fiber hydroxyl groups, affecting smoothness. These interactions and structural changes correlate with observed alterations in fabric aesthetic properties. Previous results show that F test indicate the significance difference of antimicrobial finish on stiffness property of cotton/polyester fabric [12, 13]. In current study it was observed, that in case of stiffness (warp + weft) F-test indicates that there was significance difference of antimicrobial finish on stiffness (warp + weft) on cotton/polyester fabric and the effect size was large ($\eta^2 = 0.651$). In previous studies it was indicated that antimicrobial finish did not significantly affect the smoothness of cotton/polyester fabric [14, 15]. While current study proves the same that there is no significance difference of antimicrobial finish on smoothness appearance of cotton/polyester fabric. Previous studies suggested that the three experimental groups' *A. indica*, *B. monosperma* and *L. chinensis* antimicrobial finish significantly affect the stiffness warp [16, 17]. The present study proves the same, that antimicrobial finish effects the warp stiffness of cotton/polyester fabric. In a previous study it was suggested that with the duration of 6 days the presence of microorganisms was noticed on untreated fabric [18], our results support these findings. Previous studies confirmed that the fabrics which were treated with *L. chinensis* [19-22] show 100% reduction on all three samples after 22 hours and after six days there was no colony of microorganisms was found, similar findings are observed in the present study.

5. CONCLUSIONS

This study successfully developed sustainable antimicrobial finishes from *A. indica, B. monosperma,* and *L. chinensis* leaf extracts for cotton/polyester fabrics. Results showed excellent antimicrobial efficacy, improved stiffness, and minimal impact on smoothness appearance. These eco-friendly finishes offer promising alternatives to synthetic antimicrobials, enhancing textile sustainability and consumer safety. Future research will focus on scalability, exploring new agents, and in-vivo assessments.

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7. CONFLICT OF INTEREST

The authors declare no conflict of interest.

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