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IMPACT OF ANTIBACTERIAL FINISH ON MECHANICAL PROPERTIES OF COTTON/POLYESTER TEXTILES WITH THE EXTRACT OF *AZADIRACHATA INDICA, BUTEA MONOSPERMA* AND *LITCHI CHINENSIS*

SHAMA SADAF[1], AYESHA SAEED, KOMAL HASSAN, ZEESHAN AHMAD[2]*

[1]Department of Home Economics, Lahore College for Women University
School of Science and Technology, Lahore, Pakistan

*Corresponding Author: sadaf.shama@gmail.com

Abstract

Microorganisms mainly bacteria, viruses and fungi are present everywhere around us and the textile provide the medium for the proliferation of these microorganisms which results in detrimental effects of textile and its wearer. Considering that, the study was designed to develop eco-friendly, cost-effective, antimicrobial finish extracted from the leaves of *Azadirachata indica*, *Butea monosperma* and *Litchi chinensis* plant. 50/50 cotton/polyester fabric was used to test the effectiveness of the finish. Antimicrobial finish was applied on the fabric using pad dry cure method and fixed using poly urethane binder. The presence of bacteria was assessed by ASTEM E2149 shake flask method before and after applying the antimicrobial finish and after successive 25 washes. For testing the properties of fabric, AATCC and ISO standard test methods were implemented. Moreover, FTIR, SEM and sustainability of finish to washes was also tested. Antimicrobial finish showed 100% effectiveness and resistance against bacterial strains even after 25 washes. Mechanical properties such as tensile strength and tear strength also showed significant effects on cotton/polyester fabric by applying antimicrobial finish. Similarly, significant difference of antimicrobial finish on tensile strength of weft (.010) on cotton/polyester fabric was observed with larger effect size (η^2=.74), while, significant difference was not observed on tensile strength warp of cotton/polyester fabric. It has been concluded that the natural antibacterial finish extracted from the leaves of *A. indica, B. monosperma* and *L. chinensis* may have preventive and protective role in textile used by paramedical staff, medical industry, home furnishing, athletic wears, as well as everyday use for people of all age groups.

Key words: Antimicrobial finish, *Azadirachata indica, Butea monosperma, Litchi chinensis,* Tear strength, Tensile strength.

Introduction

Finishes are the treatments applied to enhance the qualities, appearance handling or performance of textile goods. Finish on textile was applied to make it suitable for end use. There are mainly two types of finishes i.e. basic or functional. Finish applied with the aim of improvement of fabric appearance, feel and body are basic or aesthetic finishes. On the other hand, finish applied for enhancing some purposes of fabrics are antimicrobial finish, crease-resistant finish, waterproof finish, bulletproof finish or fireproof finish are the examples of functional finishes (Joshi *et al.*, 2014).

Microorganisms such as bacteria, either beneficial or pathogenic, are present everywhere around us in our environment, clothes and body. In the human body, skin, nasal cavities and genital areas are the major sites were bacteria are usually present. On textiles and clothing, bacterial species

such as *Escherichia coli* and *Staphylococcus aureus* are mainly present and are pathogenic (Sheikh et al., 2019).Antimicrobial treatment of textiles protects the wearer from pathogenic or odor-generating microorganisms that can cause health and hygiene related problems. Antimicrobial agents can either inhibit, destroy or suppress the growth of microorganisms prevent their detrimental effects such as odor, stains and spoilage. Antimicrobial agents work differently either by leaching or migrating from the surface to which they are applied (Rajendran et al., 2012, Bang et al., 2017). In this context, antimicrobial textiles should be able to inactivate a wide range of microorganisms, be non-toxic and eco-friendly, resistant to repeated washing, and easily recharged in washing or disinfection processes. In addition, the recharge agents should be non-toxic, available at home and compatible with laundry chemicals such as detergents or bleaches (Rajendran et al., 2016).

Neem leaf and its components have been shown to exhibit immunomodulatory, anti-inflammatory, anti-hyperglycemic, anti-ulcer, anti-malarial, antifungal, antibacterial, antioxidant, anti-mutagenic and anti-carcinogenic properties (Purwar, 2010).Butea monospermais uses astringent antidiarrhoeal antidysenteric febrifuge aphrodisiac cleansing anthelmintic properties. It is used for wood, resin, feed, medicine and dyes. Bark, flowers, leaves, gum and even seeds are used to make herbal medicines (Munawar et al., 2017).

A 50/50 cotton/polyester blend has been created from both fiber types to take advantage of the best properties of eachother. The 50/50 blend is breathable and tear-resistant. It is cheaper than 100% cotton and offers comparable comfort (Amutha et al., 2022). Tear strength and tensile strength were considered important factors in this study because tear resistance is a measure of how well a material can withstand the effects of tearing, whereas tensile strength is a measurement of the force required to pull something to the point where it breaks (Monteiro et al., 2014).Present research was aimed at investigating the antimicrobial properties of *A. indica*, *B. monosperma* and *L. chinensis* and their effectiveness on mechanical properties of fabrics such as tensile strength and tear strength.

Materials and Methods

This study employed true experiment with pre-test, post-test control group design (Factorial design). Two independent variables were studied –the one was 50/50 cotton/polyester fabric and other was plants (i.e. *A. indica*, *B. monosperma* and *L. chinensis* as antimicrobial agents). Antimicrobial finish was extracted from the leaves of *A. indica*, *B. monosperma* and *L. chinensis* which was applied on 50/50 cotton/polyester fabric. Plants' extractions were manipulated by making two concentration levels, in one level pure plant extraction was applied and in other level 50% concentration solution was used. Titan tensile strength tester and Elematear tearing strength tester were used for testing mechanical properties. To impart finish on fabrics, pad dry cure machine was used. FTIR and SEM test were conducted to study the effects of finish applied on all fabrics. The fabric samples were cut, treated with antimicrobial finish and then tested to govern their effectiveness as

antimicrobial fabrics. Firstly, fabrics properties of untreated samples were tested then antimicrobial finish was applied. Fabric properties were rechecked after applying antimicrobial finish whether it affected the fabric properties or not.

Table 1 ***Independent and Dependent Variables of the Study***

Independent Variables	Dependent Variables
Fabrics:	Microbial resistance
(cotton/polyester)	Presence of finish on the fabric (FTIR)
Antimicrobial plants:	Fabric tensile strength
(*A. indica*, *B. monosperma* and *L. chinensis*)	Fabric tear strength

Table 1 showed that there were two independent and four dependent variables in which plants extraction were manipulated. The control variables (control group) were the untreated fabrics upon which antimicrobial finish was not applied. In order to minimize the effect of extraneous variables (temperature and humidity), the study was conducted in testing laboratories where standard testing atmosphere was maintained.

Table 2 ***Variables of the Study***

Factors	Levels		
	1	2	3
Type of fabric		Cotton/polyester	
Anti-microbial plant	*A. indica*	*B. monosperma*	*L. chinensis*
Concentration antimicrobial extract	100%	*50%*	

Table 2 showed that there was fabric and three plants. The antimicrobial finish developed in two concentrations i.e. 50% and 100%

The presence of microorganisms and fabric properties were checked by pre-test, post-test control group design. Antimicrobial finish was applied by making two concentrations i.e.100% (pure) and 50% concentration solution. Durability of antimicrobial finish to washes was checked at 50% concentration by repeated wash cycles i.e. 5 washes intervals up to 25 washes (Figure 1).

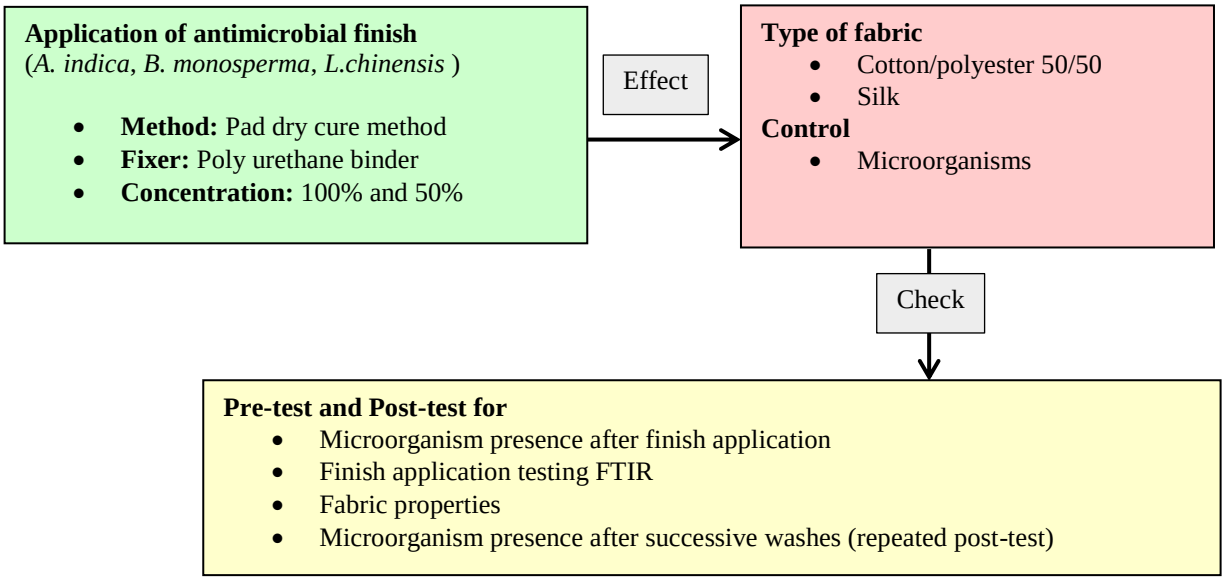

Figure 1: Theoretical Framework for the Experiment

Sample

Sample of fabric 50/50 cotton/polyester were taken from fabric trader of Faisalabad. The construction of cotton/polyester was plain weave. The weight of fabric was measured in Gsm and warp and weft yarn of fabric were counted.

Fabric Preparation

After purchasing, the fabric 50/50 cotton/polyester was first desized. In desizing, enzyme Bactasal HTN was used in ratio of 1g/litre. The pH was 5-6 and temperature was 60-70 ^{o}C. Fabric was dipped in solution for 45 minutes. After desizing, scouring was done using NaOH 4g/l and wetting agent 2g/l, detergent was used in the ratio of 1 g/l at 90 ^{o}C for 1 hour. For bleaching, took H_2O_2 5g/l, NaOH (pH 10-10.5) 2g/l, stabilizer 2g/l and sequesting agent 2g/l. The temperature of the process was 90^{o} C. The fabric was treated in this solution for one hour.

Development of Antimicrobial Finish

The leaves of *A. indica* (Neem), *B. monosperma* and *L. chinensis* were collected from the botanical garden of Government College University, Lahore in March 2014. The process can be seen in the following flowchart (Figure 2).

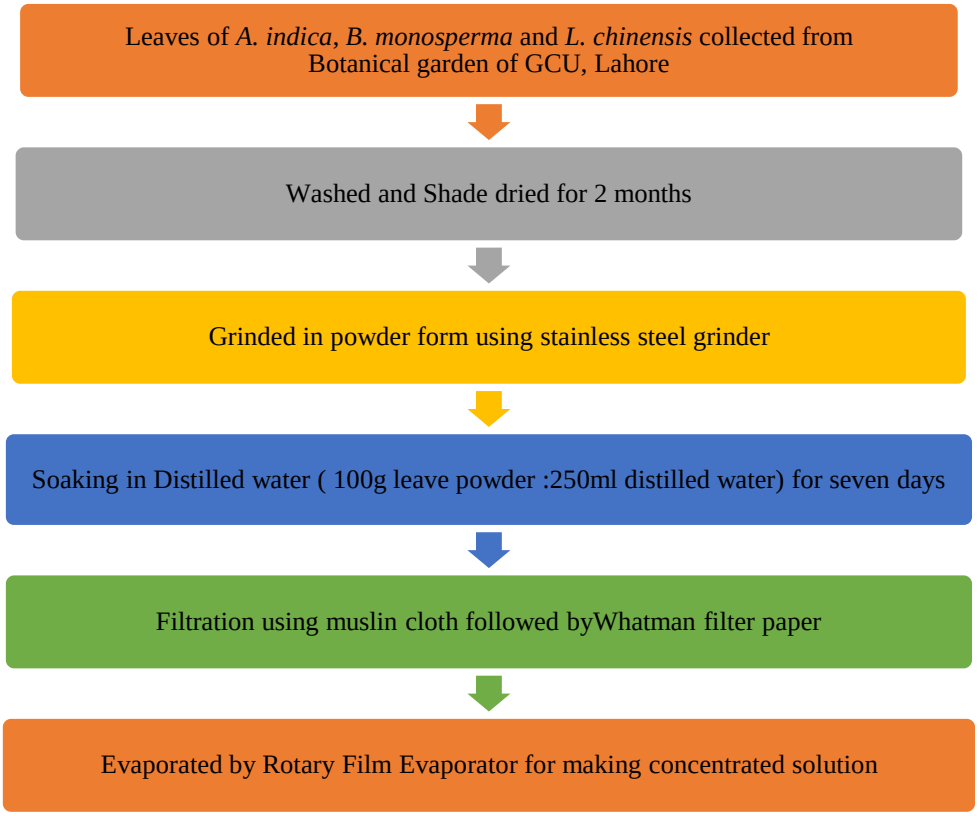

Figure 2: General Flow Diagram Showing Solvent Extraction

Took three air tight containers and labelled them A *(A. indica)*, B (*B. monosperma*) L (*L. chinensis)* and autoclaved them and distilled water (110 ^{o}C). In Laminar Air Flow Hood, powder of leaves of *A. indica*was poured in autoclave container A and autoclaved distilled water was added in it. The ratio of grinded leaves and distilled water was 100 g/250 ml. This process was repeated for *B. monosperma* and *L. chinensis*. Leave the soaked material for 7 days and stirred it twice a day. Afterwards, it was filtered using muslin cloth followed by another filtration using Whatman filter paper. The filtered extracts of *A. indica* (Neem), *B. monosperma* and *L. chinensis* were concentrated using a rotary film evaporator (Figure 2). The dilute concentration of finish was prepared in ratio of 200 ml leaves extract of *A. indica* (Neem), 50 ml poly urethane binder and 150 ml distilled water. Same ratio was used for *B. monosperma* and *L. chinensis*.After applying these concentration antimicrobial finish, microorganisms' presence was checked. The mechanical properties of fabric i.e. Tensile strength, Tear strength was checked onall fabric samples and sustainability of antimicrobial finish to home laundry was checked by five washes interval up to 25 washes and samples were cut in accordance with test requirement.

Binder

Poly Urethane Binder was used to improve the durability of antimicrobial finish to washing. It was applied on fabric by pad dry machine. The ASTEM E2149 Shake Flask

Method was used and result shown that binder has no antimicrobial property.

Preparation of Liquid Agar Medium

In a flask, 10g Tryptone, 5g yeast extract, 5g NaCl, 15g agar and distilled water was added and stirred thoroughly by hand. Solution was heated on hot plate for 5-10 minutes until fully dissolved. 1000 ml agar solution was prepared using distilled water and sealed using foil paper. This medium was then autoclaved at 121^{o}C at 15 psi for 20 minutes. After the solution cooled down pour the agar solution in plates.

Slides Preparation

In Laminar Air Flow Hood, put petri dishes, slides, spirit lamp, pipette man, wire stick and distilled water. Adjust pipette man at 10 microliters. Took a slide and put a drop of distilled water. Then, iron wire stick was taken and dipped it in spirit followed by heating it on spirit lamp until the colour turned red and finally cooled down. Then, only those petri dishes were taken on which microorganism's presence was shown by use of colony counter. Using iron wire, little bit of microorganism sample was taken and spread gently on glass slide until it was fully dissolved in distilled water. Then dried it on spirit lamp using tweezer. Afterwards, staining was carried out.

Staining Protocol

Slides were placed on frame. Flood smear with methylene blue (injected methylene blue in the smear) and left it for one minute. Drained it with iodine solution and left it for another one minute. Washed it with distilled/tap water and then drained it with decolourizer. At the end, floods with methylene red dye and left for another one minute. Then washed it. After drying these slides microorganism's presences were checked on microscope and observation were noted.

Fourier Transform Infrared (FTIR) Spectroscopy

The infrared spectra for incorporated nanofillers were obtained using Perkin Elmer Fourier transformation infrared (FTIR) spectrometer at the present school. KBr was used as a reference material for IR study. The experiment was performed in the range of 400-4000cm^{-1} with a sample scan resolution of 1cm^{-1}(Chaudhari et al., 2013, Bhuyan et al., 2015).

Fabric Properties

The antimicrobial finish was applied on 50/50 cotton/polyester. Before and after applying the antimicrobial finish mechanical properties of fabric such as tear strength and tensile strength were studied.

Tearing Strength

Tearing strength of fabrics was measured by Falling-Pendulum Type Apparatus. The tear strength as mechanical property was measured by using D 1424 – 07 standard test methods. This test process covered the purpose of the strength required to propagate a single-rip tear initial from a cut in a cloth and using a falling-pendulum type (Elmendorf) machine. A piece of fabric was cut at the centre. Sample was held among two clamps and torn through a static space. The resistance to tearing was in portion factored into the scale

reading of the apparatus and was calculated through this reading and the pendulum capability. Five samples were taken in warp direction and five samples in weft direction and their mean was calculated.

Tensile Strength

Tensile strength of fabrics was measured using the European Standard EN ISO 13934-1:1999 having the status of a British Standard ICS 59.080.30. This method was used to determine the maximum force required and elongation at maximum force using strip method.Five fabric samples were cut in warp direction and five in weft direction. Sample were set in tensile testing machine among two clamps and then the force was applied in opposite direction. At maximum force, maximum elongation was occurred and sample was ruptured and reading was recorded. All the samples should be carried out in a standard atmosphere having a relative humidity of 65 ± 2% at 21 ± 1°C (70 ± 2°F). There should be no oil, water, grease, and so forth, on the samples when experiment was conducted.

Sustainability in home laundry

The washing of fabrics samples were checked using AATCC test method 135-2003. Automatic washing machine, Automatic tumble dryer, Conditioning/drying racks with pull-out screens or perforated shelves**,** Facilities for drip drying and line drying, 1993 AATCC Standard Reference Detergent was used.

Sample was cut from fabric in standard testing atmosphere and placed on the flat surface. Laundry was done using Automatic washing machine by the following steps as washing, rinsing, and drying. During washing, automatic washing machine weighed the fabric samples and selected the water level accordingly. The temperature for washing and rinsing was less than 29°C. Afterwards, 1993 AATCC standard reference detergent was added in the ratio of 1g/l. Fabric samples were placed in washing machine and the washer cycle and time was selected. Then, the samples were rinsed and dried followed by line drying. In line dry, each sample was hung in vertical direction. Afterwards, dried the fabric samples at room temperature, not more than 26°C.

Figure 4 Microorganism's control on Polyester/cotton by *B.monosperma* after 20 washes

Figure 5 Microorganism's control polyester/cotton by *A. indica*after 25 washes

Results

Effect of Antimicrobial Finish on Mechanical Property of Cotton/Polyester Fabric

Table 4

Multivariate and Univariate Analysis: Effect of Antimicrobial Finish on Tensile and Tear strength of cotton/polyester Fabric

	Plants		
	F	P	η^2
Multivariate	72.32	.000	.995
Univariate			
Tensile Warp	1.83	.219	.41
Tensile Weft	7.65	.010	.74
Tensile Warp + Weft	.062	.979	.01
Tear Warp	5.72	.022	.68
Tear Weft	21.04	.000	.888
Tear Warp + Weft	18.03	.000	.772

Table 4 showed the results of pillai's (.00) which indicated that there was significant difference of plants on tensile strength warp, weft and tear strength warp, weft of cotton/polyester fabric and its effect size was large (η^2=.995).ANOVA was applied to find the significance difference of *A. indica, B. monosperma, L. chinensis* and control group plants extract on tensile warp, warp, weft and tear strength warp, weft of cotton fabric. The result of F test indicated that there was significance difference of Antimicrobial finish on tensile strength weft (.010) on cotton/polyester fabric and the effect size was large(η^2=.74), while there was no significance difference of antimicrobial finish on tensile strength warp of cotton/polyester fabric. The result of F test indicated that there was no significance difference of antimicrobial finish on tensile strength warp +weft (.979) on cotton/polyester fabric and the effect size was small (η^2=.01). The result of F test indicated that there was significance difference of antimicrobial finish on tear strength warp (.022) on cotton/Polyester fabric and the effect size was large (η^2=.68), F test result of tear strength weft was (.000) and its effect size was large (.888). The result of F test indicated that there was significance difference of antimicrobial finish on tear strength wrap (.000) on cotton fabric and the effect size was large (η^2=.772).

Table 5: ***Effect of Antimicrobial finish on Tensile weft and Tear warp, weft of cotton/Polyester fabric***

	Plant Name	Mean Difference (I-J)	Std. Error	Sig.[b]
Tensile Strength Weft	Control vs *A. indica*	247.459*	55.518	.002
	Control vs *B. monosperma*	125.206	55.518	.054
	Control vs *L. chinensis*	203.741*	55.518	.006
Tear Strength Warp	Control vs *A. indica*	240.000	131.656	.106
	Control vs *B. monosperma*	413.333*	131.656	.014
	Control vs *L. chinensis*	506.667*	131.656	.005
Tear Strength Weft	Control vs *A. indica*	1020.000*	154.704	.000
	Control vs *B. monosperma*	1020.000*	154.704	.000
	Control vs *L. chinensis*	966.667*	154.704	.000
Effect of Antimicrobial finish on Tensile and Tear of cotton/polyester fabric				
Tensile Strength	Control vs *A. indica*	39.142	92.422	.678
	Control vs *B. monosperma*	13.681	92.422	.884
	Control vs *L. chinensis*	16.735	92.422	.859
Tear Strength	Control vs *A. indica*	686.000*	125.618	.000
	Control vs *B. monosperma*	766.000*	125.618	.000
	Control vs *L. chinensis*	794.00*	125.618	.000

	Control Group		*A. indica*		*B. monosperma*		*L. chinensis*	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Tensile Warp	1490.95	115.71	1659.72	83.17	1578.53	440.88	1621.54	136.46
Tensile Weft	797.85	33.75	550.79	33.29	682.91	62.38	633.79	115.94
Tensile Warp + Weft	1144.40	70.99	1105.26	53.34	1130.72	249.73	1127.66	123.16
Tear Warp	5960.00	314.96	5632.00	158.49	5512.00	259.85	5328.00	95.50
Tear Weft	4764.00	225.57	3720.00	251.40	3680.00	80.00	3808.00	190.58
Tear Warp + Weft	5326.00	263.67	4676.00	199.20	4596.00	168.76	4568.00	141.84

Table 5 showed that *A. indica*, *B. monosperma* and *L. chinensis* plant extract have effect on tensile strength weft and tear strength warp, weft of cotton/Polyster fabric as compare to control group. The mean score of tensile strength warp of control group (Mean=797.85, SD= 33.75) was less as compare to mean score *A. indica* (Mean=550.79, SD=33.29), *L. chinensis* (Mean=1621.54, SD=95.50). The mean score of tensile strength warp+ weft of control group was (Mean=1144.40, SD= 70.99) as compare to mean score *A. indica* (Mean=1105.26, SD=53.34) and

B. monosperma (Mean=1130.72, SD=249.73) and *L. chinensis* (Mean= 1127.66, SD=123.16). The antimicrobial finish increased the tensile strength of treated as compare to untreated fabric. The reason was that antimicrobial finish made a coating on fabric which increased the tensile strength of treated fabric.

The mean score of tear strength warp of control group (Mean=5960.00, SD=314.96) was less as compared to *B. monosperma* (Mean=5512.00, SD=259.85) and *L. chinensis* (Mean=5328.00, SD=95.50).The mean score of tear strength weft of control group (Mean=4764.00, SD=225.57) was less as compared to *A. indica* (Mean=3720.00, SD=251.40), *B. monosperma* (Mean=3680.00, SD=80.00) and *L. chinensis* (Mean= 3808.00, SD=190.58). The mean score of tear strength warp +weft of control group (Mean=5326.00, SD=263.67) was more as compared to *A. indica* (Mean=4676.00, SD=199.20.), *B. monosperma* (Mean=4596.00, SD=168.76) and *L. chinensis* (Mean= 4568.00, SD=141.84). The antimicrobial finish increased the tensile strength of treated as compared to untreated fabric. The reason was that antimicrobial finish madea coating on fabric which increased the tensile strength of treated fabric.

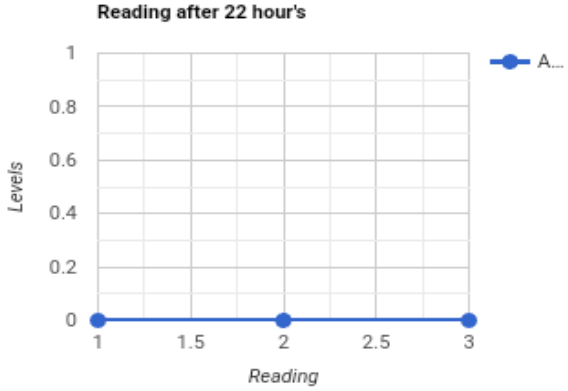

Figure 6a cotton treated with *L. chinensis*

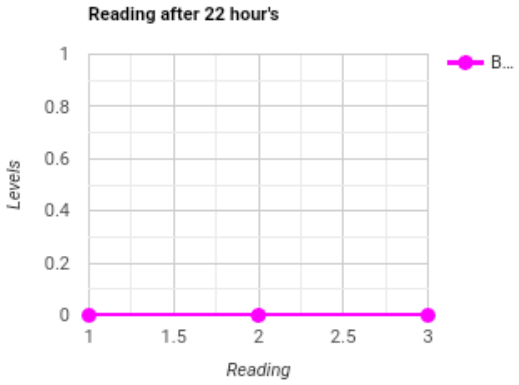

Figure 6b cotton treated with L. chinensis

Figure 6c cotton treated with L.chinensis

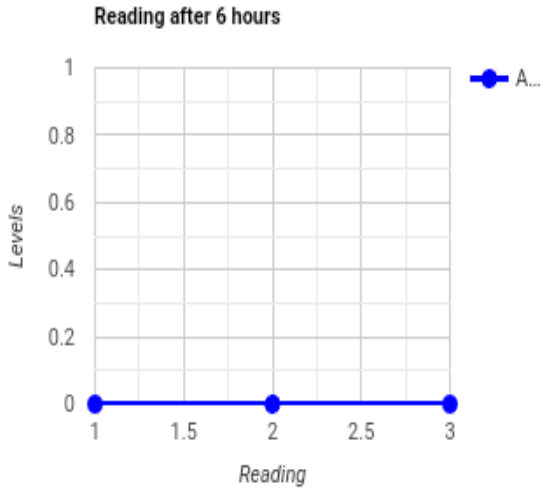

Figure 7a cotton treated with *L. chinensis*

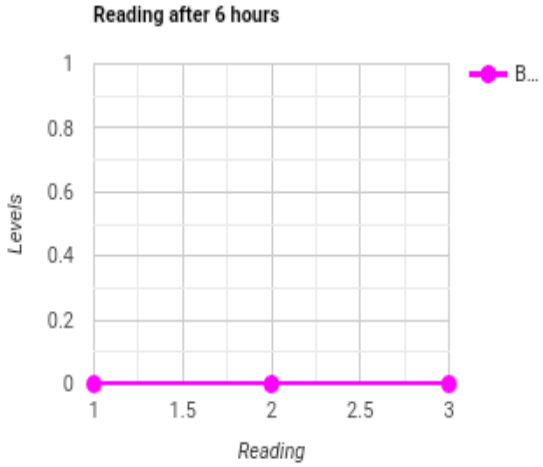

Figure 7b cotton treated with *L. chinensis*

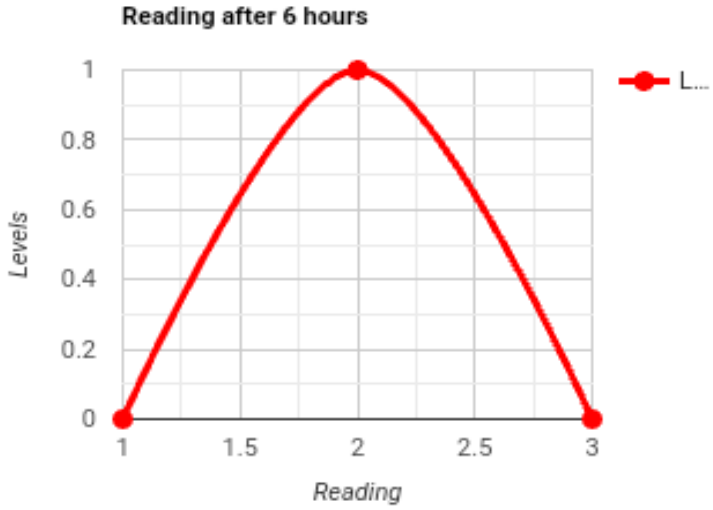

Figure 7c cotton treated with *L. chinensis*

Figures showed that after 22 hours no microorganisms' growth was observed while after six days'microorganism's growth was observed on untreated fabric.The reason was that on untreated fabric no antimicrobial treatment was applied that's why microbes' colony was more in number while microorganism presence was observed on only one out 18 treated fabric sample (application of *L. chinensis*) due to effectiveness of antimicrobial finish.

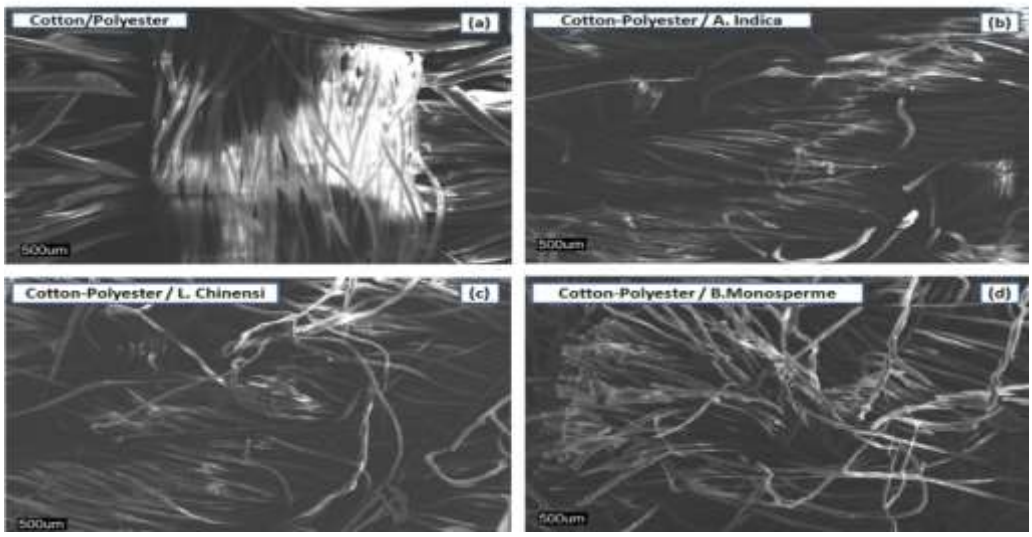

***Figure 8*: SEM micrographs of untreated and treated cotton-polyester fabric**

Figure 8 portrayed the outcome of treatment of extract on cotton/polyester fabric. Figure 8a is the SEM image of untreated cotton/polyester fabric, Figure 8b is *A. indica*, Figure 8c is *L. chinensis*, and Figure 8d is B. monosperma treated cotton/polyester fabric. It has been cleared that with the treatment, cotton/polyester fabric was affected and breakage of filament appeared on the surface of the fabric. The treated cotton/polyester fabric showed presence of finish as compare to untreated fabric.

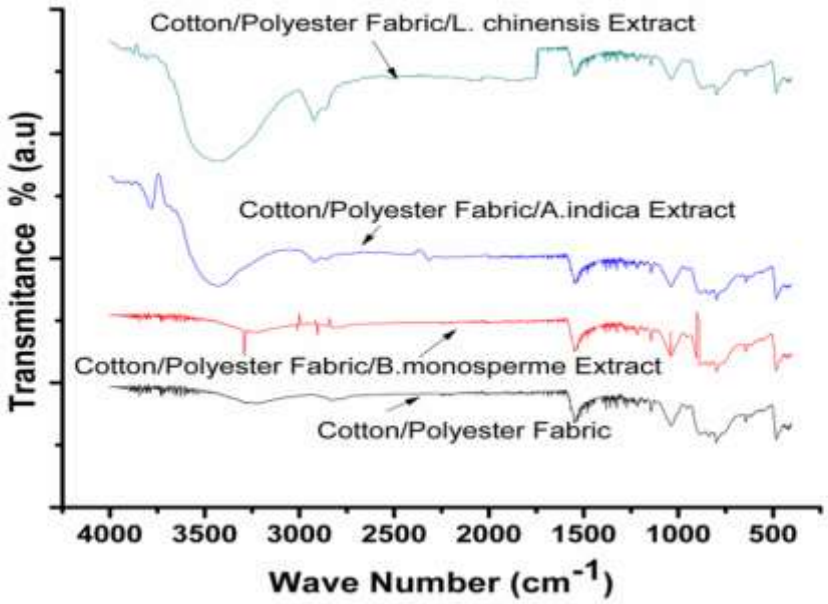

***Figure 9*: FTIR Spectra of untreated vs treated cotton/polyester blended fabrics**

The cotton-polyester blended fabric IR spectrum in Figure 1 showed that a broad peak at 1730 cm^{-1} was characteristic of carbonyl stretching of unsaturated ester. The width of the peak was reduced and the peak value has been shifted to higher wave number, that was, 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. 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 was observed at around 3600 cm-1 corresponds to free -OH groups of cellulose component 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 10 Untreated and treated fabrics after successive washes

Figure 10 showed the readings of microorganism's presence of 100% cotton, 100% polyester, 100% silk and 50/50 cotton/polyester fabric after five washes interval. The ASTM 2149 Shake Flask Method was used for microorganisms testing. In table zero mean no colony of microorganisms while one mean presence of microorganisms. On 50/50 cotton/polyester untreated and treated fabric microorganism's presence was shown after 0and 10 washes.

Discussion

In previous study, it was noted that antimicrobial finishes increased the tensile strength of fabric as, it made a coating on fabric that cause resistance in breaking when it is allowed to be stretched or pulled (Bukhari, 2019). In present study, it was noted that the antimicrobial finish increased the tensile strength of treated as compare to untreated fabric. The reason was that antimicrobial finish makes a coating on fabric which cause increase the tensile strength of treated fabric. So, previous study by Bukhari support current study.In previous study, the tearing and tensile strength was measured by F test that showrd significant difference on tearing and tensile strength before and after washes (Venkatraman, 2022). In current study, it was noted that the result of F test indicated that there was significance difference of Antimicrobial finish on tear strength warp and weft as well as tensile strength warp and weft both before and after significant washes. So thilagayathi study support current study.

The previous result of F test indicated that there was significance difference of Antimicrobial finish on tear strength wrap (.001) on cotton/polyester fabric and the effect size was large (η^2=.769) (Rajendrakumar, 2015). The current result of F test indicated that there was significance difference of Antimicrobial finish on tear strength warp (.022) on cotton/Polyester fabric and the effect size was large (η^2=.68), F test result of tear strength weft was (.000) and its effect size was large (.888). The result of F test indicated that there was significance difference of Antimicrobial finish on tear strength wrap (.000) on cotton/polyester fabric and the effect size was large (η^2=.772). So, previous study supported the current study.Previous study indicated that antimicrobial finish on tensile strength weft (.011) on cotton/polyster fabric and the effect size was large(η^2=.70), while there was no significance difference of Antimicrobial finish on tensile strength warp of cotton/polyester fabric (Periolatto, 2012).Current study showed that the result of F test indicated that there was significance difference of Antimicrobial finish on tensile strength weft (.010) on cotton/polyester fabric and the effect size was large(η^2=.74), while there was no significance difference of Antimicrobial finish on tensile strength warp of cotton/polyester fabric. So, previous study by Periolatto supported current study.

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