J. Plantarum, 8(1): 124-133

ISSN PRINT 2710-4079
ISSN ONLINE 2710-4087

EFFECT OF ANTIMICROBIAL FINISH ON MECHANICAL PROPERTY OF POLYESTER FABRIC

SHAMA SADAF[1*], AYESHA SAEED[1,] NAILA AMJAD[2]

[1]*Department of Home Economics, Lahore College for Women University,*
[2]*Department of Statistics, Lahore College for Women University,*

**Corresponding author's email:* sadafshama@gmail.com

Received on: 26-03-2025; Reviewed on: 29-01-2026; Accepted on:12-05-2026; Published on: 15-06-2026

Abstract

This study investigated the effect of plant-based antimicrobial finishes on the mechanical and functional properties of 100% polyester fabric (twill weave, 82 GSM). Crude aqueous extracts of *Azadirachta indica*, *Butea monosperma*, and *Litchi chinensis* leaves were prepared and applied to pre-treated fabric using the pad-dry-cure technique in the presence of a polyurethane binder. The fabric was scoured and bleached prior to finishing to ensure uniform treatment. Mechanical properties, including tensile strength and tear strength, were evaluated according to EN ISO 13934-1 and ASTM D1424-07 standards, respectively, in both warp and weft directions. Antimicrobial activity was assessed using the ASTM E2149 shake flask method against selected Gram-positive, Gram-negative bacteria, and fungal strains. Fourier Transform Infrared Spectroscopy (FTIR) was used to confirm the presence of functional groups associated with the applied finish, while Scanning Electron Microscopy (SEM) was employed to examine surface morphology and coating deposition on treated fabrics. The results revealed a statistically significant improvement in mechanical properties of treated samples compared to the untreated control ($p < 0.05$). Fabrics treated with *Butea monosperma* and *Litchi chinensis* extracts exhibited the highest enhancement in tensile and tear strength, which is attributed to the formation of a uniform surface coating. Antimicrobial testing demonstrated effective inhibition of microbial growth, with treated fabrics showing up to 100% reduction in microbial colonies even after repeated laundering cycles. Overall, the application of plant-based antimicrobial finishes provides an eco-friendly and sustainable approach to enhance both durability and antimicrobial performance of polyester fabrics.

Keywords: Antimicrobial Finishes, FTIR, Mechanical Properties, Tear Strength, Tensile Strength.

INTRODUCTION

Tensile and tear strength are two important mechanical properties of textile fibre, which are less focused during process formation of fabric. Out of all fabric ring spun yarn has more tensile strength (Bhaumik, 2006). Tensile and tear strength is very important in designing the military land forces garments as they are required to move, fight and survive in hostile environment. Strength of fabric is affected by many other factors including structure of fabric and yarn. On the other side government provide considerable attention to give garments to military soldiers that has great tear and textile strength. Tensile strength is defined as quantity of force required to break yarn. Change in yarn and fabric geometry depend on tear strength (Yang *et al*., 2023)

To protect human being from pathogens and to infections there is great demand of antimicrobial finishes in market. Most used antimicrobial finishes are for making soaks, clothes and other working clothes, etc. Different ways are used to apply antimicrobial finishes to a textile. The method chosen depends on different factors including use of fabric, capability of manufacturer and budget (Kampeerapappun, 2018). The microbiological world is vast and there are many microbes present in the environment. Creation and release of offensive odours will jeopardise both individual and societal health if the equilibrium of these organisms in nature is upset (Hussein *et al*., 2023).

In woven textile, tensile and tear strength is most important attribute. It effects on the tenacity of fabric. If the fabric lost tenacity value than a fabric is of no use. The age of cloth is very much affected by tear and textile strength properties. With increase of age the strength value of fabric is decreased. When a low strength fabric is required in market, it means manufacturer is using low quality yarn and fabric. Tearing strength of fabric is more considerable than other as it affects service ability. The certain finishes used in cotton fabric reduce the level of textile strength and tear property at a dangerous level. In cloth engineering, the property of woven clothing is largely affected by tensile and tear strength (Taylor, 2005).

The purpose of this research was to examine the effect of antimicrobial finish which was extracted from antimicrobial plant leaves. The antimicrobial finish was applied on polyester fabric and then tensile and tear strength was checked by pre-test and post-test. The antimicrobial finishes were cost effective and can be easily used in textile industry. It was carried out in the field of textile by use of eco-friendly (natural) product to make it worthwhile alternative to synthetic product based antimicrobial textiles. Natural plants were used to made antimicrobial finishes that lead to develop protective clothing for peoples (Hasan *et al*., 2023)

MATERIAL AND METHODS

This study investigated the effect of plant-based antimicrobial finishes on 100% polyester fabric (twill weave, 82 GSM). The independent variables included polyester fabric and plant-derived antimicrobial extracts, while dependent variables were tensile strength, tear strength, and antimicrobial activity.

Three medicinal plant species—*Azadirachta indica*, *Butea monosperma*, and *Litchi chinensis*—were selected for extraction and application as antimicrobial finishing agents. Untreated polyester fabric was used as the control sample.

Finish was added to the fabric by using the pad dry cure machine. An FTIR test was carried out to examine the finish which was applied to the fabric. The antimicrobial finish was developed in the Botany Department's lab of Government College University. Antimicrobial finish was applied in National Textile University (NTU) Faisalabad. Binder was used to improve the durability of finish. The binder was obtained from Centre for High Technology (CHT) Pakistan. Antimicrobial testing was carried out in Centre of Excellence in Molecular Biology (CEMB). FTIR test was used to check the presence of antimicrobial finish on fabric of pre-test and post-test samples 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. To investigate the effect of the antimicrobial finish on 100% polyester, first fabric 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. This part of experiment was conducted in the National Textile University, Faisalabad. The control variables (control group) of the study were the untreated fabric on 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 which have standard testing atmosphere.

Fabric Preparation

The 100% polyester fabric (twill weave, 82 GSM) was pre-treated using standard textile wet processing procedures to remove impurities and prepare the surface for finishing. Scouring was carried out using a detergent solution at a concentration of 4 g/L, and the fabric was treated for 60 minutes at standard laboratory conditions. This step was performed to remove oils, waxes, and other contaminants from the fabric surface following conventional textile pretreatment practices (7, 8).

After scouring, the fabric was bleached using a solution containing hydrogen peroxide (2 g/L), wetting agent (1 g/L), and sodium carbonate (1 g/L). The bleaching process was conducted at 70°C for 60 minutes to improve fabric whiteness and surface uniformity, in accordance with standard textile chemical processing methods (9) B. After treatment, the fabric was thoroughly rinsed with distilled water and air-dried under standard laboratory conditions.

Development of Antimicrobial Finish

The leaves of threes were collected from the Government College University (GCU) botanical garden Lahore. The plants were identified and authenticated by one of a senior researcher in the Botany Department, Government College University, and Lahore. The leaves were washed and then dried for two months under shadow. These were grinded into fine powder by stainless steel grinder. The powder was stored in airtight container The weights of dry powder of each leaf was one kg.

The three airtight containers were taken and autoclaved at (110°C temperature) the distilled water was also autoclaved. In Laminar Air Flow Hood, poured powder of leaves of *A. indica* in autoclave container then added autoclaved distilled water in it. The ratio of grinded leaves and distilled water was 100 g: 250 ml. This process was repeated for all extracts. Leave soaked material for seven days after stirring it with twice a day. After that extracts were filtered by using muslin cloth then filtered again by using Whatman filter paper. The filtered extracts were concentrated by a rotary film evaporator.

Microorganisms Observation

The microorganisms which were studied are: Gram +ve small thick rods, cluster, cocci, coccus cluster and Gram –ve such as thin short rods, dupo cocci short tail rounded, coccus, coccus bacilli, coccus diploid and fungus (yeast). These microorganisms were studied in CEMB under standard conditions. The presence of antimicrobial finish on fabric was checked by ASTEM E2149 Shake Flask Method.

Application of Dilute Antimicrobial Finish

The dilute concentration of finish was prepared in ratio 200:50:50 for distilled water, antimicrobial finishes and polyurethane binder, The three-meter sample was taken in length and twelve inch in width from polyester fabric; label untreated them as (un), (A), (B) and (L). So, there were four samples from polyester fabric. On (un) untreated polyester samples no finish was applied. On sample A, *A. indica* antimicrobial finish was applied, on sample B, *B. monosperma* leaves extract antimicrobial finish was applied and on sample L, *L. chinensis* leaves extract antimicrobial finish was applied. The untreated polyester sample was the control group and the polyester samples treated with antimicrobial finish was the experimental group. The antimicrobial finish was applied by using the pad dry cure machine in NTU. On pad dry cure machine (process) drying was done at 120 °C temperatures for 2 minutes and curing was done 150 °C temperatures for 3 minutes.

The fabric Mechanical (Tensile strength, Tear strength) properties were checked in NTU. The sustainability of antimicrobial finish to home laundry was checked by five washes interval up to 25 washes and samples were cut according to each test requirement.

Polyurethane binder was used as polymeric finishing agent which has slightly yellow color. The pH was 4.0-5.0 and it was stable to hard water and weak acid and alkalis.

Tear Strength of Fabric

The Tear Strength is a mechanical property that measured by using D1424–07 standard test method. A piece of fabric was cut at the centre, and sample was held among two clamps, the sample was torn through a static space. The resistance to tearing was in portion factored into the scale reading of the apparatus and was calculated from this reading and the pendulum capability. From the polyester fabric took five samples in warp direction and five in weft direction. Found out the mean of these five readings.

Tensile Strength of Fabrics

The Tensile Strength as mechanical property was measured by using the European Standard EN ISO 13934-1:1999 has the status of a British Standard ICS 59.080.30. This method was used to determine the tensile strength by using strip method.

Cut five fabric samples in warp direction and five in weft direction. Set sample in tensile testing machine among two clamps and force applied in opposite direction. At maximum force, maximum elongation occurred then sample rupture recorded that reading. All samples should be carried out at 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 was checked by using the test method 135-2003 mentioned in American Association of Textile Chemists and Colorists (AATCC). Following apparatus was used:

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

RESULTS

According to the findings, treated fabric did not have a microbe colony, but untreated fabric had 12 colonies of microbes. The antimicrobial finish made a coating on 100% polyester fabric.

Figure 1 shows the FTIR spectra of control and experimental groups. The high peak at 1,700 cm^{-1} affirms the possessing of COOR stretch band at 1,730 cm^{-1} and COO stretch band at 1,700 cm^{-1}. Suggesting the authentic indicators proves the existence of ester linkage and hence, the existence of ester linkage. The 1700 cm-^{1} peak indicates the presence of a hydroxyl group. The wide peak indicates the presence of a C=O stretch. The antimicrobial finish made some changes in the wavelength of fabric. So, this finish significantly affects the polyester fabric.

The results of SEM of control are shown in Figure 2. It is revealed in figure 2 that treated polyester fabric shows presence of finish as compared to untreated fabric.

On the tensile warp, weft, and tear strength warp, weft of polyester fabric, ANOVA was used to determine the significant difference between the extracts of *A. indica, B. monosperma, L. chinensis*, and control group plants.

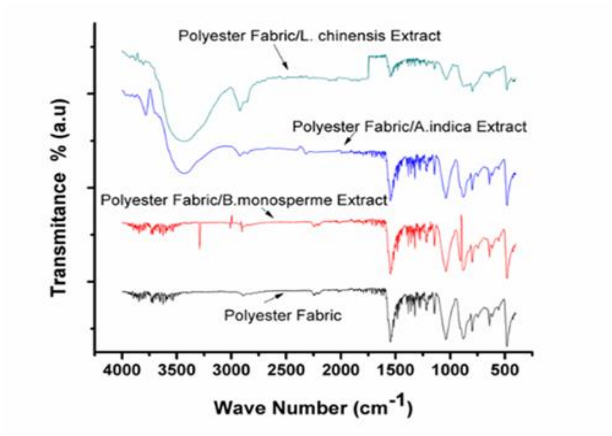

Fig. 1. FTIR Spectra of Control and Experimental Group.

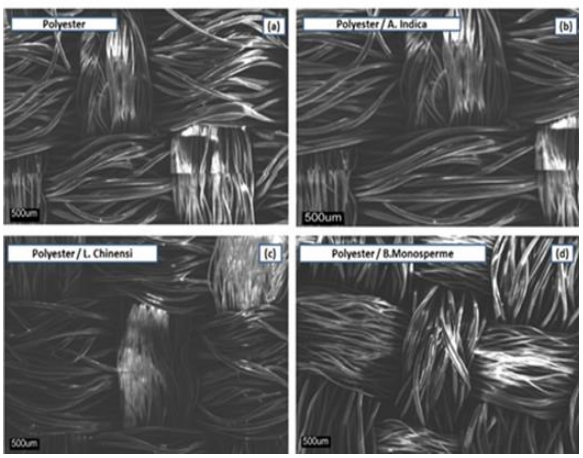

Fig. 2. Portrayed the outcome of treatment of extract on polyester fabric. Figure 2a is the SEM illustration of pure polyester, Figure 2b is *A. indica*, Figure 2c is *L. chinensis*, and Figure 2d is *B. monosperma* processed polyester fabric.

The F test result of the tensile strength warp test (0.008) indicates that there was a significant difference and that its effect size was large. Similarly, the F test result of the antimicrobial finish on tensile strength warp (0.004) on polyester fabric indicates that there was a significant difference and that it had a large effect size (2 = 0.799). (0.75). The outcome of the F test shows that there was a significant difference in the antimicrobial finish's impact on the tensile strength of the polyester fabric's warp + weft (0.061), and the effect size was substantial (η^2 = 0.36) (Table 1).

The F test result for tear strength weft was (.000) and its effect size was substantial (2 = 0.94), indicating a significant difference between the antimicrobial finish and polyester fabric's tear strength weft (.000). (.96). According to the results of the F test, there was a significant difference between the antimicrobial finish and polyester fabric's rip strength wrap (.000), and the effect size was substantial (η = .91).

A. indica and *B. monosperma* plant extract have effect on tensile strength warp, weft and tear strength warp, weft of polyester fabric as compared to control group (Table 2). The mean score of tensile strength warp of control group (Mean=436.80, SD= 56.70) was less as compared to mean score *B. monosperma* (Mean=569.93, SD=52, 52). The mean score of tensile strength weft of control group (Mean=363.63.00, SD=79.91) was less as compared to *A. indica* (Mean=406.98, SD=50.04) and *L. chinensis* was (Mean= 459.37, SD=47.07). The mean score of tensile strength warp+ weft of control group was (Mean = 400.21, SD = 66.79) as compared to mean score *A. indica* (Mean=377.45, SD=66.21) and *B. monosperma* (Mean=468.40, SD=43.27) and *L. chinensis* was (Mean= 454.85, SD=42.01). The antimicrobial finish increases the tensile strength of polyester fabric treated with *B. monosperma* and *L. chinensis*. The reason was that antimicrobial finish makes a coating on fabric which causes increase in mechanical properties.

The mean score of tear strength warp of control group (Mean=2004.00, SD=243.48) was less as compared to *A. indica* (Mean=3292.00, SD=299.20) and *B. monosperma* (Mean=3696.00, SD=261.69) and *L. chinensis* was (Mean= 3608.00, SD=204.74) (Table 3).

Table 1. Multivariate and Univariate Analysis: Effect of Antimicrobial Finish on Extensibility and Breachness of Polyester Fabric

	Plants		
	F	P	η²
Multivariate	2.01	0.138	0.84
Univariate			
Extensible comfort	10.59	.004	0.799
Extensible Weaving	8.04	.008	0.75
Extensible comfort + Weft	3.018	.061	0.36
Breach comfort	45.2	.000	0.94
Breach weaving	69.66	.000	0.96
Breach comfort + Weft	56.78	.000	0.91

Table 2. Effectiveness of antimicrobial finishes on Extensible comfort, Weave property, Breach comfort and Breach weaving of Polyester fabric.

	Sample Extract	Difference	Error (Standard)	Level of significance
Extensible comfort	Control vs *A. indica*	96.346	42.146	.052
	Control vs *B. monosperma*	-139.034*	42.146	.011
	Control vs *L. chinensis*	-30.544	42.146	.489
Extensible Weaving	Control vs *A. indica*	-71.118	27.482	.032
	Control vs *B. monosperma*	-32.877	27.482	.266
	Control vs *L. chinensis*	-128.284	27.482	.002
Breach comfort	Control vs *A. indica*	-1273.333	163.095	.000
	Control vs *B. monosperma*	-1646.667	163.095	.000
	Control vs *L. chinensis*	-1620.000	163.095	.000
Breach weaving	Control vs *A. indica*	-693.333	92.856	.000
	Control vs *B. monosperma*	-1333.333	92.856	.000
	Control vs *L. chinensis*	-800.000	92.856	.000
Effect of Antimicrobial finish on Tensile and Tear of polyester fabric				
Tensile Strength (Warp+Weft)	Control vs *A. indica*	22.764	35.331	.529
	Control vs *B. monosperma*	-68.191	35.331	.072
	Control vs *L. chinensis*	-54.638	35.331	.142
Tear Strength (Warp+Weft)	Control vs *A. indica*	-1072.000	126.720	.000
	Control vs *B. monosperma*	-1558.000	126.720	.000
	Control vs *L. chinensis*	-1236.000	126.720	.000

The mean score of tear strength weft of control group (Mean=1584.00, SD=35.78) was less as compared to *A. indica* (Mean=2440.00, SD=260.77) and *B. monosperma* (Mean=3008.00, SD=192.67) and *L. chinensis* was (Mean= 2452, SD=129.31). The mean score of tear strength warp +weft of control group (Mean=1794.00, SD=13.59) was less as compared to *A. indica* (Mean=2866.00, SD=265.), *B. monosperma* (Mean=3352.00, SD=216.15) and *L. chinensis* was (Mean= 3030.00, SD=160.31).

The Antimicrobial finish significantly affects the mechanical properties of polyester fabric. The results showed that microorganism's presence was seen after 5, 20 and 25 washes on untreated fabric while treated fabric showed 100% reduction of microbes up to 25 washes by five washes interval.

DISCUSSION

Hussein *et al.,* 2023 studied the antimicrobial finish on chitosan and chitosan PEG (polyethylene glycol) applied on polyester fabric, result revealed that it greatly affects the tensile strength. This study supports the present study. In other study Sericin was provided to fabric. It persists fo 20-40 home washes. The tensile strength is also not effective by this treatment. The results of this study support the current study for 100% polyester and 50/50 cotton/polyester fabrics (Trotman, 1984)

The findings o Gupta and Kothari (2007) are relevant to the present study as both investigations involve the application of chemical/surface modification treatments on textile fabrics and evaluation of resulting changes in physical and mechanical properties, quat-silane treatment modified the fabric structure by improving yarn stability and reducing slippage, which consequently altered tensile, tear strength, and elasticity. Similarly, in the current study, the application of an eco-friendly antimicrobial finish on cotton/polyester fabric also leads to surface-level modification of fibres, which can influence inter-fibre bonding, fabric compactness, and mechanical performance.

The slight reduction in elasticity observed by Hussein et al., (2023) corresponded with the general behavior of chemically treated fabrics, where increased stiffness or surface deposition may restrict fiber mobility. In the same way, any observed changes in tensile or tear strength in the present research can be explained through similar structural modifications induced by finishing agents. Moreover, both studies support the concept that surface treatments not only impart functional properties (such as antimicrobial activity or improved durability) but also significantly influence comfort-related properties such as flexibility and handle.

Different light weighted cotton fabric were evaluated to study strength and water resistance properties. It was founded that sateen cotton fabric was more affected in tear strength than wind resistant twill cotton fabric. If the tear strength is increased by mercerization than water resistance becomes lowered. It was also found that tear strength is much related with components of yarn and the several other factors that are related with fabric deformity like crimping (Broadbent, 2001). In a study the antimicrobial effect of polyester fabric against microbial activity is determined. A binder and dispersing agent was used for maintaining homogeneity of polyester fabric. Soil burial test was performed for determining antimicrobial effect. It was investigated that best composition of polyester fabric that give maximum antimicrobial affect was 2% ZnO, 2% binder and 1% dispersing agent. It was found that color strength affected more by antimicrobial finishes (Bonin, 2008; Doakhan et al., 2013)

In a study, polyester fabric was treated with ZnO nanoparticles, ZrO_2 nanoparticles, and catalyst, and evaluated using SEM, FTIR, and EDX analysis. The results indicated that fabric performance, functionality, and physical properties were significantly influenced by the type of substrate, fabric construction, and applied additives (Varam and Eryuruk, 2018). This is because textile substrates differ in fiber morphology, crystallinity, surface energy, and porosity, while fabric construction affects yarn arrangement and interlacing density; together these factors determine how effectively additives are deposited, adhered, and retained on the fabric surface, ultimately influencing final performance.

In the present research, an organic antimicrobial finish derived from different plant sources was applied to polyester fabric to evaluate its effect on mechanical properties. The finish was applied using the pad–dry–cure method, ensuring uniform deposition and fixation onto the fabric surface. The obtained results showed a significant positive relationship between tear and tensile strength (Brien and Weiner, 2004) which may be attributed to improved fiber–fiber interaction and surface film formation induced by the phytochemical constituents of the plant extracts.

Naggar *et al*., (2003) studied antimicrobial finish was applied on Polyethylene terephthalate fabric and the result showed that its tensile strength was improved. So, the result of this study supports the current study.

Montazer *et al.*, (2014) studied nanochitosan-polyurethane dispersions (NCS-PUs) were used as a finishing agent on polyester cotton fabric (PCF). The application used the pad dry cure process. The samples underwent tests for tear and tensile strength, as well as antimicrobial activity. However, when 10% NCS-PUs were applied, the tensile strength increased by 8.1%, and this value increased when 20% NCS-PUs were applied.

Table 3. Variability in different antimicrobial finishes on mechanical properties (Tensile and Tear Strength)

	Control Group		*A. indica*		*B. monosperma*		*L. chinensis*	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Extensible comfort	436.80	56.70	347.92	86.68	569.93	52.52	450.33	38.78
Extensible Weaving	363.63	79.91	406.98	50.04	366.88	34.69	459.37	47.07
Extensible comfort and Weaving	400.21	66.79	377.45	66.21	468.40	43.27	454.85	42.01
Breach comfort	2004.00	243.48	3292.00	299.20	3696.00	261.69	3608.00	204.74
Breach weaving	1584.00	35.78	2440.00	260.77	3008.00	192.67	2452.00	129.31
Breach weaving + comfort property	1794.00	132.59	2866.00	265.67	3352.00	216.15	3030.00	160.31

CONCLUSIONS

Naturally, there is great demand of antimicrobial finish. The antimicrobial finish extracted from plants leaves and applied on Polyester fabric.

Polyester fabric has wide applications, including use in military uniforms; however, its functional and mechanical enhancement through eco-friendly finishes has received limited attention in industrial practice. In the present study, antimicrobial finishes extracted from *B. monosperma*, *A. indica*, and *L. chinensis* were applied using the pad–dry–cure method, which promotes uniform deposition of the extract onto the fabric surface. These plant extracts contain bioactive phytochemical constituents such as polyphenols, flavonoids, tannins, and terpenoid compounds. Due to the presence of multiple hydroxyl and reactive functional groups, these compounds can interact with the fiber surface through hydrogen bonding and physical adsorption, resulting in the formation of a thin and continuous film-like coating on the fabric.

This surface coating may enhance inter-fiber cohesion and reduce yarn slippage by partially filling the inter-yarn spaces, thereby improving load distribution across the fabric structure. As a result, an improvement in tear strength can be observed. Therefore, it is suggested that such antimicrobial finishes may not only provide functional (antibacterial) performance but also contribute to improved mechanical properties, including tensile and tear strength, depending on the extent of deposition and fabric–finish interaction.

CONFLICT OF INTEREST

We have been declaring that none of us are working in publishing journal. Further, no one have any reservation, if the research is being published.There is no issue among authors and all have agreed to the inclusion of their names in the Manuscript

AUTHOR'S CONTRIBUTION

All authors contributed equally

FUNDING STATEMENT

There is not any funding to show.

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