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Research Article
Antimicrobial Properties of Cotton and Polyester/Cotton Fabrics Treated with Natural Extracts

K.B. Ravindra, Y.N. Dinesh and S.M. Chandra Sekhara

Department of Textile Technology, Bapuji Institute of Engineering and Technology, Davangere, India

Abstract

Background and Objective: Increased awareness about the hygienic lifestyle of present consumers led to the development of a range of textile products finished with antimicrobial properties. The present study focuses on the evaluation of the antimicrobial properties of cotton and polyester/cotton blend fabrics treated with bioactive agents. **Materials and Methods:** Antimicrobial compound extracted from neem and eucalyptus leaves was used for imparting antibacterial property to the test fabrics. The natural extracts at a concentration of 5 and 10% (owf) were applied on fabrics by the pad-dry-cure process. For fixation of extracts, Glutaraldehyde (8%) as cross-linking agent along with Sodium hypophosphite (2%) as catalyst was used. Qualitative and Quantitative analysis was carried out to measure the antimicrobial activity against Gram-positive and Gram-negative bacteria. **Results:** The results showed that the overall reduction of bacterial growth for treated fabrics (at 10% concentration) was more than 80 and 75% against Gram-positive bacteria (*S. aureus*) and Gram-negative bacteria (*E. coli*), respectively and after 10 standard washes, the activity was reduced by 15-20%. **Conclusion:** Phytochemical analysis of extracts confirmed the presence of bioactive compounds such as Salannin, Nimbin, Azadirachtin in neem extract and Tannins, Phenolic compounds, Flavonoids in eucalyptus extract.

Key words: Bioactive compound, cross-linking agent, inhibition, bacterial growth, wash durability

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Corresponding Author: K.B. Ravindra, Department of Textile Technology, Bapuji Institute of Engineering and Technology, Davangere, India

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Increased awareness about the hygienic lifestyle of the present generation led to the development of a range of textile products finished with antimicrobial properties. The inherent properties of the textile fibres, the structure of the substrate provide ideal conditions for the growth of microorganisms. Cross infection by pathogens leads to the development of odour when the fabric is worn next to the skin. The microbial attack leads to discolouration and loss of functional properties of fabrics such as elasticity and tensile strength. Because of this, to protect the wearer and the textile substrate itself antimicrobial finish is applied to textile materials[1].

The most commonly used chemical-based antimicrobial agents considered for the production of antimicrobial textiles are silver and silver compounds, Copper, Zinc, Triclosan, Quaternary ammonium compounds, Polyhexamethylene biguanide, N-halamine compounds etc. Many of the commercial antimicrobial agents currently available in the market are synthetic, expensive and are not environment friendly. The active ingredients used in antimicrobial finishing need to be effective, have selective activity towards undesirable microbes, non-toxic, safe, biodegradable and durable to wash[2].

Extracts from various parts of some of the medicinal plants and herbs such as the leaves, stems, flowers, fruits, roots, seeds and barks, etc. exhibit antimicrobial properties. These antimicrobial compounds, which are mostly extracted from plants (Aloe vera, tea-tree, eucalyptus, neem, grapefruit seed, tulsi leaf etc.), include phenolics and polyphenols (Simple phenols, phenolic acids, quinines, flavonoids, flavones, flavonols, tannins and coumarins), terpenoids, essential oils, alkaloids, lectins, polypeptides and polyacetylenes[3]. These components show, not only antimicrobial but also antioxidant properties. If developed an eco-friendly, reusable and durable antimicrobial textile which are effective against harmful pathogens will be beneficial for both medical industry workers and the general public as well.

The active components of neem are found in all parts of the tree but in general, bark, seeds, leaves and roots are used for extraction. The important active compounds found in many parts of the neem tree are limonoids, Azadirachtin, Nimbin and salannin[4].

Eucalyptus leaves contain up to 14% of the major components of tannin and flavonoids as minor components. The major bioactive components for inhibiting microbes are ά-terpineol and 1-8-cineole[5]. The present study emphasized the antibacterial activity of the extracts of Neem and Eucalyptus plants.

MATERIALS AND METHODS

Fabrics and study area: This study was carried out at Bapuji Institute of Engineering and Technology, Davangere, Karnataka, India, recently. In this study, for the application of active compounds two varieties of fabrics, viz 100% plain cotton and polyester/cotton woven fabrics in the bleached state were used. The test fabrics were sourced locally and the construction particulates are shown in Table 1.

Extraction of active compound: Leaves of Neem tree and Eucalyptus tree were used for the extraction of natural antimicrobial compounds. Leaves were dried in shade and later at 40 ºC in a drier. The dried leaves were powdered into fine particles and the active compound was extracted by the maceration method. The active compound in powder form was taken in a beaker and kept in contact with the Ethyl alcohol (solvent) for 3 days at room temperature. To increase its polarity, the contents were continuously stirred every 2 hrs. The extracts were collected and subjected to concentrate using a rotary evaporator at 40°C in a condition of reduced pressure. It was stored at 4°C and was utilized for the finishing of fabrics.

Application of bioactive agent on test fabrics: Natural extracts (5 and 10% owf) were applied on the cotton and polyester/cotton fabric samples along with glutaraldehyde (8%) as a cross-linking agent and Sodium hypophosphite (2%) as a catalyst using conventional pad-dry-cure process. Fabric samples were padded through a laboratory padding mangle at temperature 40-50°C with two dips and two nips to give a wet pick up of 85±5% (owf). Later the samples were dried at 85°C for 5 min and then cured at 120°C for 2 min.

Evaluation of antimicrobial activity: For the study, test bacteria Staphylococcus aureus (gram-positive) ATCC 6538 and Escherichia coli (gram-negative) ATCC 11230 were used. Evaluation of antimicrobial activity for untreated and treated fabric samples was carried out by both qualitative and quantitative methods.

Table 1: Construction particulars of test fabrics

Specifications	Cotton fabric	Polyester/cotton blended fabric (67/33)
Ends/cm×picks/cm	40×36	40×33
Yarn count (tex)	12×13	14×12
Fabric weight (GSM)	113	115

Antimicrobial activity by the qualitative method: The untreated and the treated fabric samples were tested and antimicrobial activity was determined by using agar diffusion test AATCC 147-2004. Bacterial cells were inoculated on nutrient agar plates over which fabric samples (discs of 12 mm diameter) were laid for intimate contact. These nutrient agar plates were then incubated at 37°C for 18-24 hrs and observed for the growth of bacteria directly underneath the fabric samples and immediately around the edges of the fabrics (zone of inhibition). Antimicrobial activity is indicated by the absence of bacterial growth directly underneath the fabric sample and the formation of an inhibition zone around the fabric sample.

Antimicrobial activity by the quantitative method: The untreated and the treated fabric samples were tested and antimicrobial efficiency was determined in terms of % reduction of bacterial growth using modified colony counting method (AATCC test method 147-1998).

Wash durability: The finished fabrics were washed (10 and 20 cycles) using standard detergent (3% on owf) at 40°C in an automatic washing machine using method ISO 6330-1984E. The fabric samples were then subjected to antimicrobial tests.

Phytochemical analysis: Phytochemical analysis of the plant extracts was carried out as per the standard methods to know the presence or absence of various phytocompounds.

RESULTS AND DISCUSSION

Evaluation of antimicrobial activity by agar diffusion test (qualitative) AATCC 147-2004: The antimicrobial activity of the test fabrics treated with plant extracts was studied by the disc diffusion method (AATCC 147-2004). The level of antibacterial activity of fabrics treated with Neem and Eucalyptus plant leaves extracts was assessed by examining the extent of bacterial growth in the contact zone between the agar and the specimen and the width of the inhibition zone around the specimen. Figure 1 and 2 showed the Petri plates containing treated fabric samples after incubation. All the treated fabric samples showed significant inhibitory activity as is evident from the complete absence of bacterial growth underneath the samples. It is observed that the zone of inhibition for the samples treated with neem and eucalyptus at 10% concentration as expected was slightly greater than at 5% concentration.

Figure 1(a and c) showed the formation of a zone of inhibition for treated samples against *E. coli* and *S. aureus* bacteria respectively. This is due to the diffusion of the active compound around the edges of the specimens. The diameter of inhibition zones for the washed samples was found to be minimal or absent indicating removal of the unfixed antimicrobial compound during washing in Fig. 1(b and d). However, there was no microbial growth underneath the samples. This suggests that the active compound was bound to the fibre substrate and successfully inhibited bacterial growth. The absence of the formation of a zone of inhibition around the discs indicates that the active compound present in the fabric disc was not diffused and instead attached to the fabric firmly (due to cross-linking effect). This means the cotton and polyester/cotton fabric samples treated with neem extract inhibited the growth of both Gram-positive and Gram-negative bacteria successfully. This result is supported by Patel Margi H *et al.*[6]. They reported that the eucalyptus extract has antimicrobial activity against gram-negative bacteria (*E. coli*) as well as gram-positive bacteria (*S. aureus*).

Figure 2(a and c) show the formation of a clear zone around the eucalyptus treated fabric specimen which is due to the leaching of the active compound. Whereas after washing, zone size is reduced or absent due to removal of the unfixed antimicrobial agent which is shown in Fig. 2(b and d).

It is also understood that the eucalyptus extract of 10% concentration (owf) would be sufficient to give maximum inhibition for the growth of both gram-positive and gram-negative bacteria. This observation is in agreement with the research findings of Saroj Yadav *et al.*[7]. They found that the eucalyptus treated fabric inhibits the growth of both gram-negative bacteria (*E. coli*) and gram-positive bacteria (*S. aureus*).

From the experiments, it was observed that the antimicrobial activity of fabrics treated with neem extract was found to be the highest followed by eucalyptus. Concerning fibre substrate the antimicrobial activity of all the treated cotton fabrics is more than treated polyester/cotton fabrics. This may be due to a higher level of cross-linking of the extract by cotton compared to polyester/cotton blended fabric.

Evaluation antimicrobial activity by suspension test (quantitative) (AATCC test method 147-1998): The test results in Table 2 and 3 showed the antimicrobial activity of the fabrics treated with neem and Eucalyptus extracts. It can be observed that fabric samples treated with extract alone (without cross-linking) could retain only 15-18% activity after 5 wash cycles and 5-9% activity after 10 wash cycles. This type of temporary finish is suitable only

E. coli 5 and 10% *S. aureus* 5 and 10%

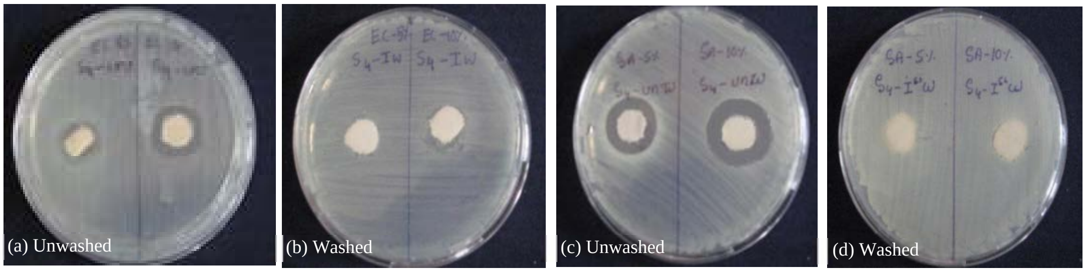

Fig. 1(a-d): Zone of inhibition for Neem extract-treated fabric (a-b) unwashed and washed against *E. coli* and (c-d) unwashed and washed against *S. aureus*

E. coli 5 and 10% *S. aureus* 5 and 10%

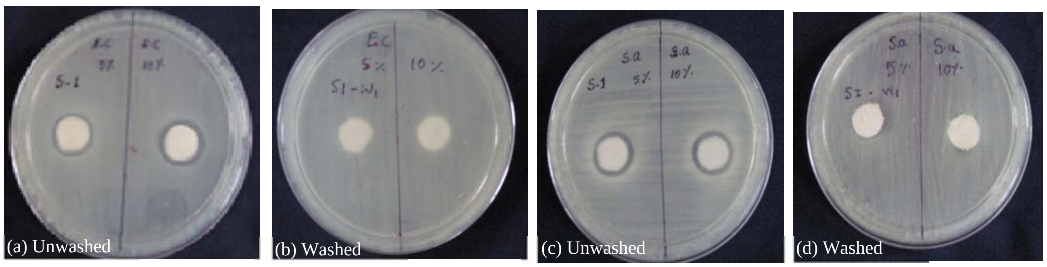

Fig. 2(a-d): Zone of inhibition for Eucalyptus treated fabric (a-b) unwashed and washed against *E. coli* and (c-d) unwashed and washed against *S. aureus*

Table 2: Antimicrobial activity of test fabrics treated with neem

		Reduction of bacterial growth (%)					
		S. aureus			*E. coli*		
Fabric	Conc. (%) owf	Initial	5 wash	10 wash	Initial	5 wash	10 wash
Cotton	5.0 without cross linking agent	62	15	5	55	8	3
	5.0	65	55	48	60	52	48
	10.0	90	75	65	85	72	60
Polyester/cotton	5.0 without cross linking agent	59	13	5	54	6	3
	5.0	62	51	46	59	51	45
	10.0	87	72	61	81	69	57

Table 3: Antimicrobial activity of test fabrics treated with eucalyptus

		Reduction of bacterial growth in (%)					
		S. aureus			*E. coli*		
Fabric	Conc. (%) owf	Initial	5 wash	10 wash	Initial	5 wash	10 wash
Cotton	5.0 without cross linking agent	50	10	2	48	6	2
	5.0	65	57	46	62	50	45
	10.0	86	78	60	82	75	62
Polyester/cotton	5.0 without cross linking agent	47	9	2	46	5	2
	5.0	63	55	44	60	49	42
	10.0	83	76	57	78	72	60

for fabrics that do not need frequent washing as in disposable hygiene applications. However, the treated samples co-applied with a cross-linking agent could retain antimicrobial activity above 80% after 5 washes and above 50% after 10 washes. Hence if it is required to have a durable finish that can withstand repeated launderings, so these natural plant products can be applied to fabrics in combination with a cross-linking agent.

Table 4: Qualitative analysis of phytochemical screening of extracts

Compound	Parameters	Results
Eucalyptus	Tannins	+
	Phenolic compounds	+
	Flavonoids	+
Neem	Salannin	+
	Nimbin	+
	Nimbidol	-
	Azadirachtin	+

Neem: The antimicrobial effectiveness of neem treated fabrics is shown in Table 2. The cotton fabric treated with 10% neem extract showed a 90% reduction against *S. aureus* and an 85% reduction against *E. coli*. However, the polyester/cotton fabric sample at a similar concentration showed bacterial growth reduction of 87% against *S. aureus* and 81% against *E. coli* (Table 2). It is also observed that the percentage reduction of bacterial growth is increased as the concentration of the antimicrobial agent is increased. However, there is a reduction of antimicrobial activity for washed samples, which is in line with research by Joshi M *et al.*[4].

The cross-linking agent is actively involved in bond formation between fibre and the active ingredients in neem extract. The crosslinking agent can act as a bridging material for chemical bond formation with the neem limonoids[8].

Eucalyptus: The test results of eucalyptus treated fabrics are presented in Table 3. Eucalyptus treated fabrics (with a cross-linking agent) show 83-86% reduction of bacterial growth against *S. aureus* and 78-82% against *E. coli* (slightly less than neem treated fabrics). The eucalyptus treated fabrics retained antimicrobial activity up to 62% after 10 washes which are found to be satisfactory. Tannins, flavonoids and 1-8-cineole are the active antimicrobial ingredients (phytochemicals) present in eucalyptus extract that inhibit bacterial growth. Ben Fadhel *et al.*[9] reported similar results for the antimicrobial properties of eucalyptus extract.

Phytochemical analysis: The Phytochemical analysis of the extracts showed the presence of various bioactive components. The details are shown in Table 4. The phytoconstituents like alkaloids, glucoloids, saponins and flavonoids or antibiotic principles of plants and these antibiotic principles are actually the defensive mechanism of plants against different pathogens.

The preliminary phytochemical screening of eucalyptus extracts showed the presence of bioactive components like tannins, flavonoids, phenolic compounds and neem contains Salannin, Nimbin and Azadirachtin (Table 4).

CONCLUSION

The antimicrobial efficiency of cotton and polyester/cotton fabrics treated with Neem and Eucalyptus extract was found to be above 75% against Gram-positive and Gram-negative bacteria. From the experiments, it was also observed that the antimicrobial activity of fabrics treated with these extracts is higher in cotton than in cotton/polyester blended fabric. Though there is a slight reduction in the antimicrobial efficiency after repeated washing, the treated fabrics retained a considerable amount of antimicrobial activity which will be sufficient to inhibit bacterial growth. The bioactive components extracted from neem and eucalyptus are found to be suitable for finishing fabrics in the production of health care products like hospital clothing and domestic hygiene products.

SIGNIFICANCE STATEMENTS

Phytochemical screening tests confirm the presence of phytochemicals like Salannin, Nimbin, Azadirachtin in neem and Tannins, Phenolic compounds, Flavonoids in eucalyptus. Hence it may be inferred that natural plant extracts such as Neem and Eucalyptus can be successfully used to impart antimicrobial properties to cotton and polyester/cotton textiles. This study discovered the possibilities of using natural plant extracts as eco-friendly antimicrobial finishing agents and replace chemical compounds which are harmful to human health. Also, the findings of this study help the researchers to uncover the critical areas of eco-friendly antimicrobial finishing of textiles using bioactive compounds.

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