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SYNERGISTIC ANTIMICROBIAL EFFECTS OF PLANT EXTRACTS ON TENCEL FABRICS TREATED WITH NATURAL FINISH

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ABSTRACT

Plant extracts are rich sources of bioactive compounds with anti-microbial properties. Tencel is a regenerated fibre derived from wood pulp of eucalyptus, spruce and beech trees. The present study was conductedin 2024 to investigate the synergistic effect of antimicrobial properties of Tencel fabrics treated with natural finish developed from a combination of plant extracts. *Chrysopogon zizanioides* (L.) Roberty (CZ), or vetiver, is a fragrant grass which has been used in the treatment of various skin infections due to its antimicrobial properties. Extracts from *Kaempferia galanga* L., *Cassia fistula* L. and *Chrysopogon zizanioides* (L.) Roberty in different proportions were used for developing the natural finish. Aqueous plant extracts were used to apply natural finish on to the Tencel fabric. The antimicrobial properties of treated Tencel fabrics were evaluated against both gram-positive and gram-negative bacteria using AATCC TM90 method and compared with the untreated fabric. The study revealed that fabric sample treated with a combination of CZ, KG and CF extracts produced the largest zones of inhibition for both bacterial strains. Thus, it is inferred that plant extract combination can be used as textile finish to enhance the antimicrobial properties of the fabrics since a synergistic effect is observed.

Key words: Antimicrobial, *Cassia fistula, Chrysopogon zizanioides, Kaempferia galanga*, Natural finish, Plant extracts, Tencel

INTRODUCTION

Tencel is a regenerated fibre derived from wood pulp of eucalyptus, spruce and beech trees. It is a fibre that is considered to be eco-friendly since it can be manufactured using recycled solvent. It is a cellulosic fibre which is used to replace cotton in several applications.(Afroz and Islam, 2021). Tencel is the trade mark recorded by Courtaulds Fibres Ltd. Company and the generic term for Tencel is Lyocell(Chen, 2015). Studies showed that the fabrics made from 100 percent Tencel showed high water vapor permeability and air permeability than the fabrics made from cotton and cotton blends (Afroz *et al.*, 2022). Any finish that is applied to Tencel fabrics will be better absorbed. As there is an emphasis on pollution control and biological protection in the current scenario, developing some natural finishes will be more beneficial to improve the quality of human life. To avoid the fabric borne infections, development of antimicrobial textiles

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can be a better choice. However, the Tencel fabric itself lacks the intrinsic antimicrobial properties. Still the properties can be imparted to the fabric by means of special finishes or dyes. Tencel fabrics that were dyed with pomegranate peel showed antibacterial properties (Rehman *et al.*, 2018).

There were several findings that illustrate the use of natural plant extracts in different solvents as potential antimicrobial agents. The effectiveness of different plant extracts in inhibiting microbial growth depends on the species of plant, the part of the plant used, and the solvent used for extraction (Banu *et al.*, 2024) have been studied. A study conducted using the alcoholic extracts of *Cassia fistula* leaves showed that the gram-negative bacteria were more sensitive to the finish applied using the extracts than gram-positive ones (Seyyednejad *et al.*, 2014).Oil extracted from Vetiver [*Chrysopogon zizanioides* (L.) Roberty syn. *Vetiveria zizanioides* (L.) Nash] commonly known as khas-khas, khas, khus-khus or khus grass exhibited a moderate ability against gram-positive bacteria, especially *Staphylococcus aureus (S.aureus)* in the antimicrobial assay (David *et al.*, 2019). The biological activities of *C. zizanioides* showed that they can act as a natural remedy for different conditions like cancer, diabetes, convulsions, inflammation, depression and bacterial infections (Grover *et al.*, 2021).Several studies demonstrated the traditional use of *Kaempferia galanga* L. in treating bacterial and fungal diseases like skin, diarrhoea and dandruff (Kumar, 2020). Extracts of *K.galanga* in different solvents showed good in-vitro antibacterial and antifungal effects. The present study focused on analysing the antibacterial activity of the Tencel fabric treated with aqueous extracts from *Kaempferia galanga* L., *Cassia fistula* L., and *Chrysopogon zizanioides* (L.) Roberty. The study also investigated synergistic effect of antibacterial properties of Tencel fabric treated with plant extracts,by treating with both isolated form and in combination, which acted as natural finishes.

Table 1.Specification of Tencel fabric

Features	Description
Fibre	100% Tencel
EPI (Ends Per Inch)	124
PPI (Picks Per Inch)	64
Weave	2 X 1 Twill
GSM	130
Count	30 X 30

MATERIAL AND METHODS

Fabric used for the study was desized and bleached Tencel fabric with the specifications shown in table 1. Different parts of three different plants *Kaempferia galanga* L., *Cassia fistula* L., and *Chrysopogon zizanioides* (L.) Roberty were used for the study and are shown infigure 1. *Kaempferia galanga* L. is a rhizomatous herb which finds its application in medicines, perfumes, food etc. *Cassia fistula* L. is a tree found throughout Kerala and has both ornamental and medicinal value. *Chrysopogon zizanioides* (L.) Roberty syn. *Vetiveria zizanioides* (L.) Nash is also found throughout Kerala and used in medicines, basket making, perfumes etc. The sources were identified by Dr.Sreekumar V.B., Principal Scientist of Forest Botany Department, Kerala Forest Research Instititute (KFRI), Peechi, Thrissur, Kerala and voucher specimens are deposited at KFRI herbarium. Table 2 shows the parts of these sources used for conducting this study.

Preparation of extract

The rhizomes, leaves and roots from the sources were washed thoroughly and dried in shade. The dried rhizomes, leaves, and roots were shredded into small pieces and then ground to fine powder. Aqueous extracts of the

Kaempferia galanga L.

Cassia fistula L.

Chrysopogon zizanioides (L.) Roberty

Fig. 1. Plant sources used for study

powdered samples were prepared by the following procedures. Figure 2 shows the powdered form of the plant sources.

Kaempferia galanga L.: 20g of shade dried powder of rhizomes was simmered with 600ml of water for a period of 20 mins and filtered. The filtered liquor was concentrated to 200ml by boiling.

Cassia fistula L.: 20g of shade dried powder of leaves was simmered with 400ml of water for a period of 20 mins and filtered. The filtered liquor was concentrated to 200ml by boiling.

Chrysopogon zizanioides (L.) Roberty: 20g of shade dried powder of roots was simmered with 400ml of water for a period of 20 mins and filtered. The filtered liquor was concentrated to 200ml by boiling.

The rhizome powder of *Kaempferia galanga* produced a viscous extract. It required a higher solvent volume of 600ml for greater dilution to maintain effective simmering and prevent scorching during the simmering process. The leaf powder of *Cassia fistula* and root powder of *Chrysopogon zizanioides* yielded extracts that were less viscous and manageable with 400ml of solvent. All filtrates were reduced to 200ml, which ensured comparable extract strengths for further applications. The concentrated extracts were stored under refrigeration.

Application of natural finish

Plant extracts were used to prepare the finishing bath at a concentration of 50g/L. The material liquor ratio was taken as 1:20. 20 ml solution was taken from the 50 g/l aqueous extract of the natural sources. The fabric was immersed in the aqueous solution with plant extractsfor one hour duration. Different proportions of the extracts were used to study the effect of combining extracts from different sources. Table 3 shows the samples that are used for the study treated with different proportions of extracts

Antibacterial assay

The AATCC TM90 Antibacterial Assay was used to evaluate the effectiveness of the natural finishes given to the fabrics.For

Table 2.Specification of Sources

Common Name	Plant Name	Part Used
Sand ginger	*Kaempferia galanga* L.	Rhizomes
Golden Shower Tree	*Cassia fistula* L.	Leaves
Vetiver grass	*Chrysopogon zizanioides* (L.) Roberty	Roots

Kaempferia galanga L.
Rhizomes powder

Cassia fistula L.
Leaves powder

Chrysopogon zizanioides
(L.) RobertyRoots powder

Fig. 2. Powdered form of plant sources used for the study

qualitative testing of antimicrobial activity of textile and leather materials AATCC TM90 agar diffusion method is used.(Nguyen *et al.*, 2023)

Maintenance of Bacterial Culture: The growth method is performed as follows: At least three to five well-isolated colonies of the same morphological type were selected from an agar plate culture. The top of each colony is touched with a loop, and the growth was transferred into a tube containing 4 to 5 ml of a suitable broth medium, such as Nutrient broth. The broth culture was incubated at 35^0C until it achieves or exceeds the turbidity (usually 2 to 6 hours). The turbidity of the actively growing broth culture was adjusted with sterile saline or broth to obtain turbidity. This results in a suspension containing approximately 1 to 2 x 108 CFU/ml for *S.aureus* and *Escherichia coli (E.coli)*

Inoculation of Test Plates:Optimally, within 15 minutes after adjusting the turbidity of the inoculum suspension, a sterile cotton swab was dipped into the adjusted suspension. The swab should be rotated several times and pressed firmly on the inside wall of the tube above the fluid level. This will remove excess inoculum from the swab.The dried surface of a Nutrient agar plate was inoculated by streaking the swab over the entire sterile agar surface. This procedure was repeated by streaking two more times, rotating the plate approximately 60^0 each time to ensure an even distribution of inoculum. As a final step, the rim of the agar was swabbed.The lid was left ajar for 3 to

Table 3. Samples treated with different proportions of extracts

Proportion of extracts used*	Sample
Untreated Sample	Sample 1
100% CZ	Sample 2
100% CF	Sample 3
100% KG	Sample 4
50% CF+ 50% CZ	Sample 5
50% CF + 50% KG	Sample 6
50% CZ+50% KG	Sample 7
33.3% CZ+33.3% KG+33.3% CF	Sample 8

*KG: *Kaempferia galanga* L., CF: *Cassia fistula* L., CZ: *Chrysopogon zizanioides* (L.) Roberty

5 minutes, but no more than 15 minutes, to allow for any excess surface moisture to be absorbed before placing the sample.The fabric of 2.2cm diameter is placed over the agar. Further, the petriplates were placed inversely for complete diffusion and inhibition zones were examined by measuring the diameter (mm) formed around the well after 24 hrs incubation at 37°C. The zones were measured by using standard (Hi-Media) scale. Agar diffusion method was used to study zone of inhibition of Tencel fabric dyed with pomegranate peel. (Rehman *et al.,* 2018)

RESULTS AND DISCUSSION

A comparison of antibacterial activity against gram negative bacteria -*E.coli* and gram positive bacteria –*S.aureus* is shown in Table 4 and Figure 3.

The antibacterial activity of Tencel fabrics that were given natural finishes, were assessed against the gram positive bacteria –*S. aureus* and gram negative bacteria –*E. coli* using the zone of inhibition method. The results, represented in table 4 and figure 3, show that:

Sample 1, the untreated fabric exhibited no antibacterial activity, showing a 0 mm zone of inhibition for both *S. aureus* and *E. coli*.

Sample 2 and Sample 3 fabrics that are treated with single source CZ and CF respectively did not show any zone of inhibition for either bacterial strain, indicating no antibacterial activity in the given concentration.

Sample 4, the Tencel fabric treated with KG demonstrated moderate antibacterial activity, with a 5 mm zone of inhibition against *S.aureus* and a 16 mm zone against *E. coli*, indicating a better efficacy against E. coli.

Fabric sample 5, treated with a combination of CF and CZ showed some anti-bacterial activity. It showed a 5 mm and 19 mm zone of inhibition against *S.aureus* and *E. coli* respectively. The hydro-alcohol extracts of *Cassia fistula* L. leaves was reported to show prominent antimicrobial activity against bacteria and fungi (Singh *et.al,* 2023).Five compounds present in *Chrysopogon zizaniodes* (L.) Roberty root were identified to be responsible for the antibacterial activity (Ramírez-Rueda *et al.*, 2019).

Fabric sample 6, treated with CF and KG also exhibited antibacterial activity, with a 10 mm inhibition zone for *S.aureus* and 26 mm zone for *E. coli*. The antibacterial property of *Kaempferia galanga* may be attributed to the presence of polar compounds such as genetic

Table 4. Assessment of antibacterial activity of treated Tencel fabrics

Samples	Zone of Inhibition (mm)	
	Staphylococcus aureus	***Escherichia coli***
Sample1: Untreated	0mm	0mm
Sample 2: CZ	0mm	0mm
Sample 3:CF	0mm	0mm
Sample 4: KG	5mm*	16mm*
Sample 5: CF+CZ	5mm*	19mm*
Sample 6: CF +KG	10mm*	26mm
Sample 7: CZ+KG	20mm*	5mm*
Sample 8: CZ+KG+CF	26mm	22mm

*Beneath the fabric there is a zone of inhibition or there is no bacterial growth

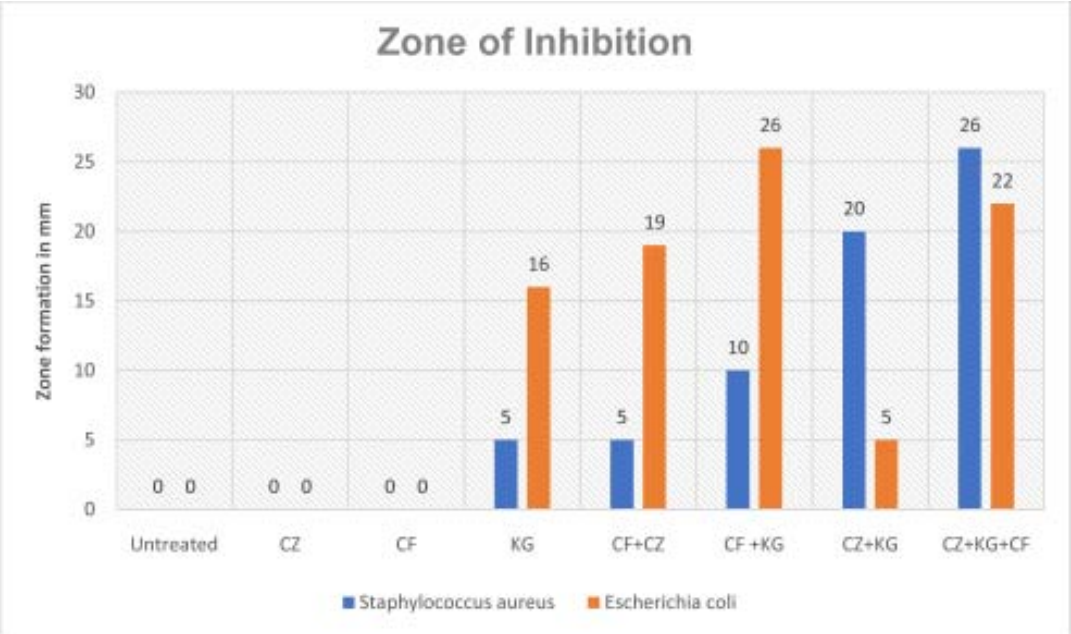


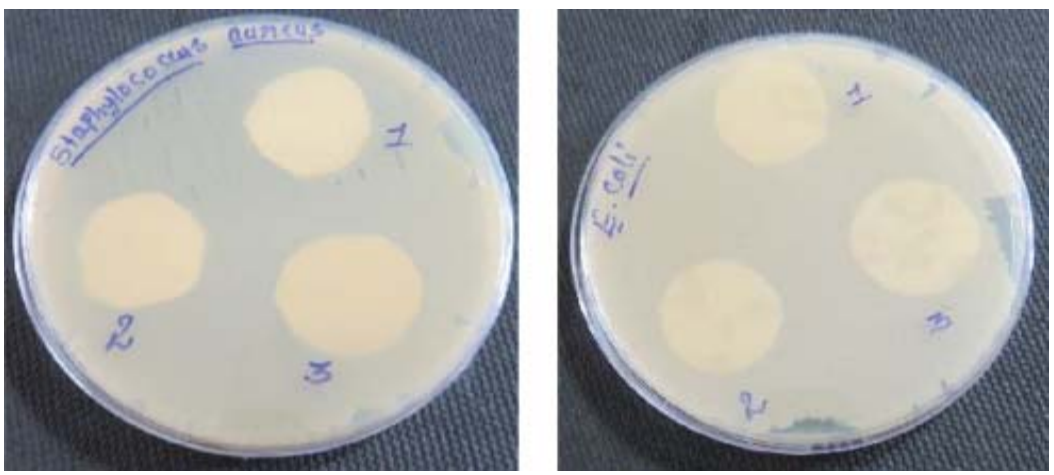
Fig. 3. Zone of inhibition formed by treated Tencel fabrics

acid, syringic acid, apigenin and cinnamic acid (Men *et al.*, 2024).

Sample 7 which is treated with the combination of CZ and KG displayed the highest inhibition against *S.aureus* with a 20 mm zone of inhibition but was found less effective against *E. coli*, with only a 5 mm zone.

Fabric sample 8 treated with a combination of CZ, KG and CF produced the largest zones of inhibition for both bacterial strains, with 26 mm against *S.aureus* and 22 mm against *E. coli* which suggests a strong synergistic effect of all three extracts.

The antibacterial assessment shows that the untreated Tencel fabric (Sample 1) and those treated with plant extracts of *Chrysopogon zizanioides*(Sample 2) and *Cassia fistula* (Sample 3) did not exhibit any zones of inhibition. This indicates minimal antibacterial effect at the given concentration. Higher concentrations may be necessary to achieve greater activity.*Kaempferia galanga*



1- Untreated, **2**- 100% CZ, **3**-100% CF

4- 100% KG, **5**- 50% CF+ 50% CZ, **6**-50% CF + 50% KG

7- 50% CZ+50% KG, **8**- 33.3% CZ+33.3% KG+33.3% CF

Fig.4. Antibacterial activity of Tencel fabric treated with natural finishes

(Sample 4) exhibited moderate antibacterial activity, especially against *E.coli*. Improved activity was observed in the combined treatments (Samples 5 to 8). The combination of extracts demonstrates the potential for synergistic effects in antibacterial applications, with sample 8 (CZ+KG+CF) demonstrating the highest efficacy against both the bacterial strains.(Wijayawardhana *et al.*, 2021)

CONCLUSION

The combination of the extracts of *Kaempferia galanga*, *Chrysopogon zizanioides*, and *Cassia fistula* exhibited maximum antibacterial activity although individual plant extracts did not exhibit prominent antibacterial properties. This makes them suitable for treating the fabric as a natural finish aimed at reducing bacterial growth on fabrics.A synergistic effect of the extracts was observed on the Tencel fabric treated with the plant extracts.

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