Journal of Natural Fibers

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/wjnf20

Musa Acuminata Leaves Extract Impedes Bacterial Growth and Ultraviolet Protection in Cotton Fabric

B. Mothilal, S.Kubera Sampath Kumar, C. Prakash, K. Harish Kumar, B. Venkatesh, S. Sivamani & G. Karthikeyan

To cite this article: B. Mothilal, S.Kubera Sampath Kumar, C. Prakash, K. Harish Kumar, B. Venkatesh, S. Sivamani & G. Karthikeyan (2022) *Musa Acuminata* Leaves Extract Impedes Bacterial Growth and Ultraviolet Protection in Cotton Fabric, Journal of Natural Fibers, 19:15, 10269-10278, DOI: 10.1080/15440478.2021.1993495

To link to this article: https://doi.org/10.1080/15440478.2021.1993495

Published online: 02 Nov 2021.

JOURNAL OF NATURAL FIBERS
2022, VOL. 19, NO. 15, 10269–10278
https://doi.org/10.1080/15440478.2021.1993495

Taylor & Francis
Taylor & Francis Group

Musa Acuminata Leaves Extract Impedes Bacterial Growth and Ultraviolet Protection in Cotton Fabric

B. Mothilal[a], S.Kubera Sampath Kumar[b], C. Prakash[c], K. Harish Kumar[d], B. Venkatesh[e], S. Sivamani[f], and G. Karthikeyan[g]

[a]Department of Fashion Technology, Sona College of Technology, Salem, India; [b]Department of Chemical Engineering (Textile Technology, Vignan's Foundation for Science, Technology & Research (Deemed to Be University), Guntur, , , India; [c]Department of Handloom and Textile Technology, Indian Institute of Handloom Technology, Fulia, Ministry of Textiles, Govt. Of India, Shantipur, Nadia, India; [d]Footwear Design and Development Institute (FDDI), Raidurgam, Hydarbad, 500104, India; [e]National Institute of Fashion Technology, Hyderabad, Telangana, 500081, India; [f]Chemical Engineering Section, Engineering Department, University of Technology and Applied Sciences (Salalah College of Technology), Salalah, Sultanate of Oman; [g]Department of Textiles Technology, K S Rangasamy College of Technology, Namakkal, India

ABSTRACT

In this study, the methanol extract of *Musa acuminate* leaves has a significant development on the quality of the protection features such as, antibacterial and ultraviolet protection, was observed. The fabric finished with a higher concentration of *M. acuminata* sap (7%) at the temperature rate of 40–50°C has higher zone of inhibition against gram-positive bacteria and improved ultraviolet protection factor than the controlled sample. The fabric finished with the lower concentration of *M. acuminata* sap (3% & 5%) has lesser zone of inhibition against gram-positive bacteria. The fabric finished with a 7% concentration of *M. acuminata* leaves methanol extract at 40–50°C shows high protection factor against antibacterial and ultraviolet protection. Hence, it is observed that the fabric finished with a higher concentration of *M. acuminata* sap exhibits a higher zone of inhibition against bacteria's and ultraviolet protection factors when compared to the lower concentration of methanol extraction of *M. acuminata* leaves.

摘要

本研究中对山茱萸叶甲醇提取物的质量有显著的发展, 对其抗菌、防紫外线等防护特性进行了观察. 与对照样品相比, 在40-50°C的温度下, 使用更高浓度的M.acuminata sap (7%) 整理的织物对革兰氏阳性细菌具有更高的抑制区, 并提高了紫外线保护系数. 用较低浓度的尖灭支原体M.acuminata sap (3%和5%) 整理的织物对革兰氏阳性菌的抑制区域较小. 在40-50°C的温度下, 用7%浓度的尖叶千里光叶甲醇提取物整理的织物具有很高的抗菌和防紫外线保护系数. 因此, 可以观察到, 与较低浓度的甲醇提取物相比, 使用较高浓度的M.acuminata sap整理的织物对细菌和紫外线保护因子具有更高的抑制区域.

KEYWORDS

Antibacterial activity; banana leaf; FTIR; methanol extraction; *Musa acuminata*; ultraviolet protection

关键词

抗菌活性; 香蕉叶; 甲醇萃取; 紫外线防护

Introduction

Bacteria are microorganisms that stay alive on textiles for several days. They act as conductors/transmitters of diseases (González-Montelongo, Lobo, and González 2010). Textiles are prone to the accumulation of bacteria. Humans can be safely protected from pathogens by wearing clothes of antimicrobial property. The antibacterial property of a textile fabric can be evaluated

CONTACT C. Prakash dearcprakash@gmail.com Department of Handloom and Textile Technology, Indian Institute of Handloom Technology, Fulia, Ministry of Textiles, Govt. Of India, Shantipur, Nadia, West Bengal 741402, India.

based on a percent reduction in bacteria and extent of inhibition to the growth of bacteria. There has been enormous research on attributing antibacterial properties to textile materials. Consumers look for clothes that provide comfort, freshness, odorless, and are bacteria-repellent to wear (Pachiayappan, Prakash, and Kumar 2020; Prakash et al. 2021; Ramesh et al. 2017). The bacterial genera *Bacillus, Streptomyces*, and *Pseudomonas* degrade textiles (Szostak-Kotowa 2004). Microbial development on textiles can result in unpleasant odors, physical discomfort, tensile strength loss, and fabric decolorization. Synthetic fibers are frequently resistant to microbial attack due to their hydrophobic nature and weak adsorption capacity, which makes it difficult for microbial enzymes to break their carbon bonds (Gao and Cranston 2008). While home laundering is permitted for textiles, its effectiveness in reducing microbial contamination is dependent on personnel compliance. Laundering must be combined with other control practices for maximum effectiveness of decontamination.

Clothing protection factor is a major criterion, which having influence on the antibacterial properties, ultraviolet protection factors. Hence, this research is focused on controlling bacteria and UV protection by finishing of fabric with methanol extract of *M. acuminata* leaves. *M. acuminata* stem sap was naturally extracted by cutting the cultivated plant just 1½ feet above from the ground level where the SAP flow is relatively uniform and making a pit over it, helps to exude the sap due to the higher root pressure. Around 35 to 40% of sap was obtained from a total *M. acuminata* plant component. According to the growth and soil nutrient each plant exudes approximately around 5 l of Sap within 48 h (Kumar et al. 2014; Mathew and Negi 2017).

Methanol is a more polar protic solvent to ensure that a wide polarity range of compound could be extracted. Methanol is a very good extractant for chlorophylls from the plant leaf. Methanol can be used as a potential solvent for extraction of secondary metabolites from the leaves. It is a widely used and effective solvent for extraction of antioxidants and total phenolic compounds. Methanol having high solubility of polyphenols in this solvent due to the hydrogen force between polyphenols and proteins (Adeel et al. 2021; Felhi et al. 2017; Rathinamoorthy et al. 2014).

Ultraviolet rays are harmful to human health. The conduction of ultraviolet rays through fabrics is significantly retarded by modifying the textile parameters such as, fiber type, chemical composition, fabric constitution, additives, and textile processing aids, color, and fabric finish. UV-protected textiles absorb the ultraviolet rays and block the transmission through the fabric to the skin. *M. acuminata* plant leaves are considered as a potential resource of natural antioxidant and antibacterial properties. The constituents segregated from banana leaf have been analyzed by earlier researchers (Balakrishnan, Wickramasinghe, and Wijayapala 2019; Mothilal et al. 2020; Sango et al. 2018). Jaswal, AgyaPreet, and Goel (2017) focused on development of herbal finished fabric using *Murraya koenigii* (curry leaves) and *Zingiber officinale* (ginger) oil and they studied the physical property performance such as stiffness and tensile strength of both treated and untreated fabric samples. From their study, it was observed that no negative effects on physical properties of fabric after finish application. The finished fabric is increased with a minimal amount of stiffness, but it is not significant to affect the handle of the fabric when worn on human skin. Gupta et al. (2017) was conducted to develop antibacterial and UV protective cotton fabric by using plant extract. *Syzygium cumini* leaves were extracted via Soxhlet method and was coated on cotton fabric by using pad-dry-cure process. From the result it was found that the application of UV protective finish on cotton fabrics by using *S. cumini* (L.) leaves extract improved UV protective properties to a greater extent, leading to excellent protection. This new plant source exhibiting, UV protective property can be used for development of medical textiles as well as for apparels for daily use.

The present study also provides a new source for natural plant material which can be combined with new technologies such as micro-encapsulation and nanotechnology to develop effective and durable textile materials. In this work, the qualitative and quantitative analysis of

antibacterial properties, ultraviolet protection value and identification of functional groups and components through Fourier transform infrared (FTIR) of methanol extract of *M. acuminata* leaves were communicated.

Materials and methods

Materials

Cotton fabric

The plain cotton fabrics were produced by conventional weaving machine (power loom) with cotton of 40 s count in both warp and weft. The technical parameters of the unfinished fabric are given below in Table 1.

Musa acuminata leaves and stem sap

The materials used in the development of antibacterial and UV-protected textile material coated with methanol extracts of *M. acuminata*. The mature *M. acuminata* leaves in raw form were collected from Salem city, Tamil Nadu, India (11.6643° N, 78.1460° E). The solvent (methanol) was purchased at Madras Scientific Center, Salem, Tamil Nadu, India. Deionized water was used for all experiments. Analytical grade was done by the help of all other chemicals and reagents. The materials used in the development of comfort and moisture management of textile material coated with naturally extracted *M. acuminata* stem sap. *M. acuminata* stem saps in raw form were collected in Salem zone, Tamil Nadu, India. Deionized water was used for all experiments to make the sap into different concentration level.

Preparation of methanol extract of *Musa acuminata* leaves

Fresh and healthy leaves and stem sap of *M. acuminata* plants were collected and rinsed with plain water and then with distilled water. At the room temperature, the leaves and sap was dried in shadow. About 250 g of the shadow-dried leaves and sap were taken, garbled, and ground into small units of size ranging from coarse particles to fine powder. As the particles were of smaller size, they dissolved in the methanol solvent rapidly and with ease. Ten grams of dried powder of *M. acuminata* plant leaf was mixed up with 100 ml of 80% methanol in a conical flask. The magnetic stirrer is used for 7 days with completely closed manner to be kept. After such incubation, the solution was filtered through filter paper. The filtered solution was evaporated at room temperature. The powder was scrapped and collected as super nature precipitates. Then, with the participation of distilled water as per required concentration were prepared by the powder was dissolved. Thus, methanol extract was prepared.

Table 1. Detailed technical parameters of cotton fabrics.

Characteristics	Cotton Fabric
Weave structure	Plain
Ends per inch (EPI)	92
Picks per inch (PPI)	82
Warp count (Ne)	40's
Weft count (Ne)	40's
Warp crimp %	7
Weft crimp %	9
Warp cover factor	14. 5
Weft cover factor	12. 5
GSM (gms)	1. 14
Warp twist direction	S twist
Weft twist direction	S twist

Finishing of fabric with methanol extract

A prescribed amount of methanol extract was taken, and mixed thoroughly. Cotton fabric samples of about 2.5 kg were made ready for finishing. The fabric samples were washed with distilled water and boiled for 30 min at a maximum temperature of 60°C. The fabric sample was boiled and taken out. Then, finishing is proceeded with *Musa acuminata*. The *Musa acuminata* leaf methanol extract was coated on their sample by using padding mangle and by impregnating in a bath of material–liquid (M: L) ratio 1:10. The fabrics specimens were dried at room temperature to drive out the moisture content present in them. The methanol extract coated samples were tested for their antibacterial activity, adopting standard procedures.

Antimicrobial activity assessment

AATCC-147-1998 (USA) – qualitative assessment of finished fabric, working agar diffusion test: An in-vitro test was carried out to assess qualitatively the antibacterial activity of the *M. acuminata* leaf methanol extract coated sample against *Staphylococcus aureus* (ATCC 6538), a gram-positive microorganism and *Escherichia coli*, a gram-negative microorganism, using nutrient agar, purchased from M/s T. Stanes & Company Limited, Coimbatore, Tamil Nadu, India. Nutrient agar plates were prepared by pouring 15 ml of nutrient agar medium into sterile Petri dishes. The dishes were referred to solidify for 5 min, and 0.1% inoculate suspension was smeared uniformly and the inoculate was left to dry for 5 min. *M. acuminata* leaf methanol extract-treated fabric of 2.0 cm diameter was kept on the surface of the medium, and the plates were incubated at 37.5°C for 24 h. After completion of incubation, the fabric sample was taken out and the zone of inhibition formed in the fabric was measured in millimeters and the readings were recorded.

AATCC-147–1998 (USA) – quantitative assessment of finished fabric, servicing broth dilution tests: The antibacterial activity of the *M. acuminata* leaf methanol extract treated specimens were evaluated quantitatively against *S. aureus* and *E. coli* bacteria, by following the procedures of AATCC 100 test method. Unfinished fabric and *M. acuminata* leaf methanol extract-finished fabric samples of 4.8 cm diameter were placed in a 50 ml conical flask containing 0.5 ml of bacterial inoculates. After completion of incubation over a contact period of 24 h at 37°C, the broth solution was serially diluted. The diluted solution was poured on nutrient agar plates and incubated for 24 h at 37°C. Colonies of bacteria received from the agar plate were quantified, and the percent reduction of bacteria (R) was calculated using the following equation: $R\ (\%) = [((B - A) \times 100)/B]$, where A is the number of bacterial colonies from treated specimen after inoculation over a 24-h contact period, and B is the number of bacterial colonies from untreated control specimen after inoculation over a 24-h contact period.

Evaluation of ultraviolet protection factor

A swatch of fabric specimen was kept underneath with a mild tension on the transmittance port of the integrating sphere. Spectra of fabric samples had been amassed from 280 to 400 nm using VISION lite Materials Calc software. According to AS/NZS 4399:1996, EN 13758–1:2001, and AATCC 183:2004, the VISION lite Materials Calc software automates the determination of UPF, average UVA transmittance, and average UVB transmittance.

Fourier transform infrared analysis

Fourier transform infrared (FTIR) spectroscopy is used to discern the chemical compounds occupied in a substance/product. The wavenumber of light absorbed is salient feature of the chemical bond as can be seen in the annotated spectrum (Geethu et al. 2014). The methanol extract of *M. acuminata* powder was used for FTIR analysis. The powdered sample of each extract was loaded in FTIR spectroscope (Shimadzu, Japan), with a scan range from 400 to 4000 cm^{-1} with a resolution of 4 cm^{-1}. All the analysis was repeated thrice and mean ± SD was recorded. The presence of functional group was identified and noted.

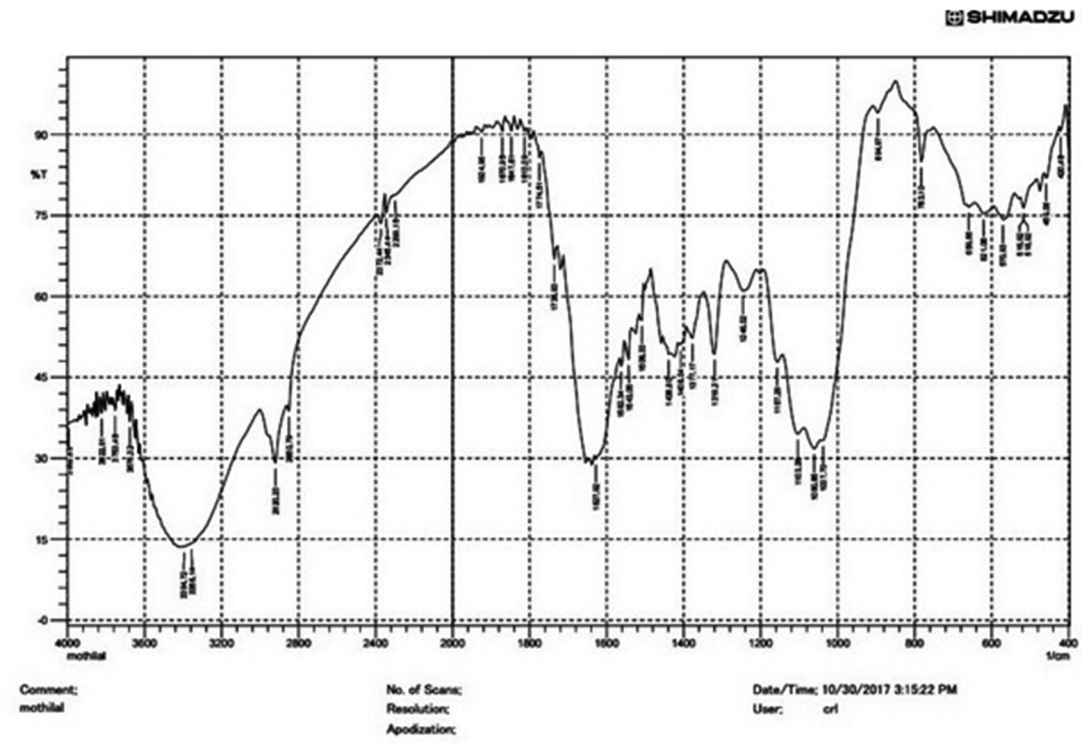

Figure 1. FTIR graph of *Musa acuminata* leaf extract.

Table 2. FT-IR peak values of methanol extract from *Musa acuminata* (Banana leaf).

Wavenumber (cm^{-1})	Functional group	Components
3753	O-H	Phenols
3394	N-H stretch	Amines
2920	H-C = O	Aldehydes
2345	C-O stretch	Carbonyl group
1627	C-N bend	Amide
1508	Aromatic skeletal lignin	Lignin
1060	C-O	Hemicellulose
898	Amorphous cellulose	Cellulose

Results and discussions

FTIR analysis of the *Musa acuminata* leaf extract

The components present in the *M. acuminata* leaf extract were studied using an analytical instrument, namely, Shimadzu IRTracer-100 FTIR spectrophotometer. The FTIR spectra of raw *M. acuminata* leaf were examined and are presented in Figure 1.

Typical functional groups and the corresponding bands for each component of the *M. acuminata* leaf are shown in Table 2. It is observed that all samples exhibit two main transmittance regions: one at the low wavenumber (700–2000 cm^{-1}) and another at high wavenumber (2000–3800 cm^{-1}). *M. acuminata* leaf methanol extract contains carbon compounds of the phenol group which binds to proteins in-vitro forming soluble and insoluble complexes (Torti, Dearing, and Kursar 1995).

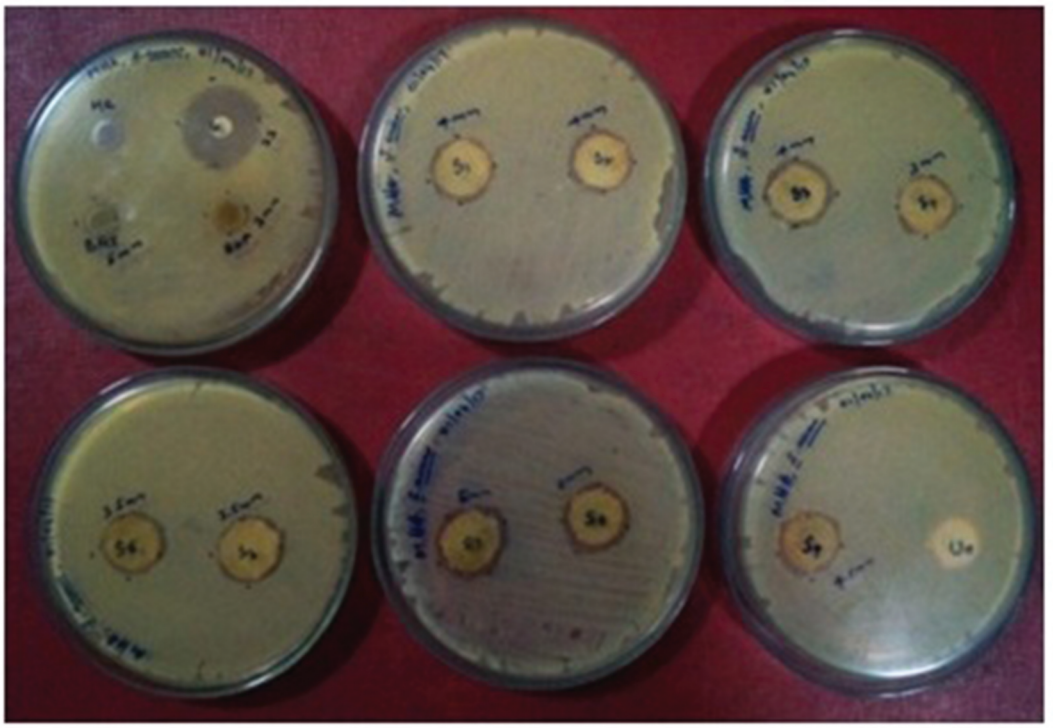

Figure 2. Antibacterial properties against *S.aureus.*

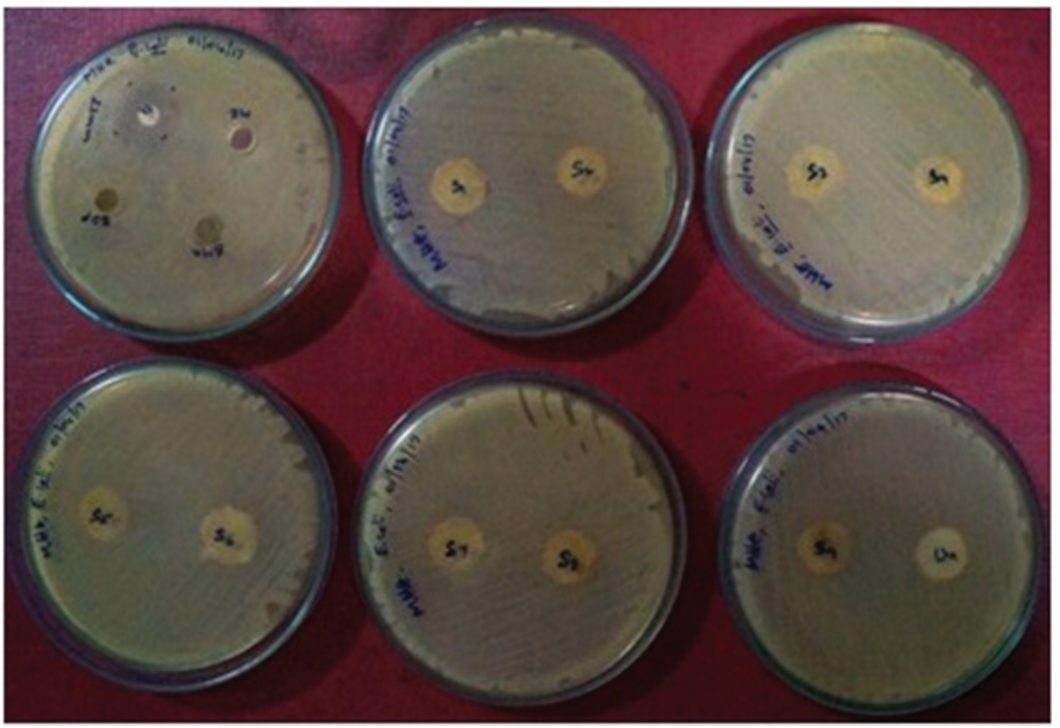

Figure 3. Antibacterial properties against *E. coil.*

Table 3. Antimicrobial activities against *S. aureus & E. coil* by zone of inhibition.

S. No	Sample Description	Sample code	Zone of Inhibition in mm	
			S. aureus	*E. coli*
1	3% concentration @ RT	S1	2. 5	Nil
2	3% concentration @ 40°C	S2	3	Nil
3	3% concentration @ 50°C	S3	3. 5	Nil
4	5% concentration @ RT	S4	3. 5	Nil
5	5% concentration @ 40°C	S5	4	Nil
6	5% concentration @ 50°C	S6	4	Nil
7	7% concentration @ RT	S7	4. 5	Nil
8	7% concentration @ 40°C	S8	5	Nil
9	7% concentration @ 50°C	S9	5	Nil
10	Untreated Cloth	UN	Nil	Nil
11	Gentamycin −120 mcg	G	23	23
12	Banana Methanol extract (Liquid)	BME (100 µl)	5	Nil
13	Banana Methanol extract (Powder)	BDP (5 mg)	3	Nil
14	Methanol	ME (100 µl)	Nil	Nil

Table 4. Reduction percentage of bacteria for cotton fabric.

S. No	Sample Description	Sample code	Percentage of reduction of *S. aureus* count
1	3% concentration @ RT	S1	>44. 16%
2	3% concentration @ 40°C	S2	>49. 33%
3	3% concentration @ 50°C	S3	>53. 27%
4	5% concentration @ RT	S4	>46. 21%
5	5% concentration @ 40°C	S5	>51. 62%
6	5% concentration @ 50°C	S6	>55. 88%
7	7% concentration @ RT	S7	>49. 11%
8	7% concentration @ 40°C	S8	>53. 78%
9	7% concentration @ 50°C	S9	>58. 88%
10	Untreated Cloth	UN	Nil

Antibacterial assessment

From the Figures 2 and 3, it was found that *M. acuminata* leaf methanol extract inhibited the growth of *S. aureus* bacteria only and did not have any significant impact on the growth of *E. coli* bacteria. The zone of inhibition in the treated specimens was wider with respect to *S. aureus* as shown in Figure 2.

The tests were carried out five times. The widest zone of inhibition was found in samples S8 and S9 (5.00 ± 0.87 mm) followed by sample S7 (4.50 ± 0.33 mm), samples S5 and S6 (4.00 ± 0.57 mm), samples S3 and S4 (3.50 ± 0.52 mm), sample S2 (3.00 ± 0.82 mm), and sample S1 (2.50 ± 0.28 mm) as data appear in Table 3.

M. acuminata leaf methanol extract produced the broadest zone of inhibition (23.00 mm) under positive control (Gentamycin -120 mcg), with reference to both *S. aureus* and *E. coli* bacteria. The percent reduction of bacteria, in the case of *Staphylococcus aureus*, is listed in Table 4. It is noted that the percent reduction of bacteria and the zone of inhibition increase with an increase in the concentration of the extract and temperature.

All the samples show a significant difference ($p < 0.05$) in the results of zone of inhibition in mm and percent reduction of bacteria with varying concentrations and temperature. The p values in both qualitative and quantitative analyses are 0.017778, 0.000462 and 9.415–06, 0.000121, respectively, which is less than 0.05.

From this experimental study, it is believable that *M. acuminata* leaf methanol extract can be very well applied to finish fabrics to impart antibacterial property. Skin and soft tissue infections in the form of abscesses, furuncle wounds, injuries, burns, and surgical wounds caused by *S. aureus* can be treated using medical textiles coated with *M. acuminata* leaf methanol extract (Harris, Foster, and Richards 2002).

Ultraviolet radiation protection factor

Parameters that influence the ultraviolet radiation protection factor (UPF) of a fabric are the composition of yarns, tightness of the weave, color, stretch, moisture, and finishing. UPF value strongly depends on the chemical structure of the fiber and the additives present in it. An elevated relationship exists between the UPF and the fabric porosity. UPF also depends on the type of fiber. A finished fabric derives its UV resistance from the aforesaid properties. It is also duly enhanced by the fortification of the fabric with *M. acuminata* leaf methanol extract. The results of ultraviolet radiation resistance – UPF, UV transmission %, and UV absorbance %, pertaining to untreated and treated cotton fabrics appear in Table 5. Due to the higher absorbance of UV radiation by fabric treated with *M. acuminata* leaf methanol extract, the UPF value of treated fabric is marginally higher than that of normal untreated fabric.

Data analysis: variance statistics

Statistical analysis was performed by using the SAS System (version 8 for Windows) to conclude with added importance of result, for antibacterial properties, UV protection factor, and FTIR of the fabric finished using methanol extract of *M. acuminata* leaves. ANOVA testing was conducted to analyze the statistical importance of finishing fabric with extracted leaves on antibacterial properties, UV

Table 5. UPF factor values for treated and untreated cotton fabric.

Sample	UPF Factor	UVA	UVB	UV %
Untreated	40	3. 62	2. 42	97. 38
Treated	41	3. 89	2. 72	97. 98

Table 6. Two-way ANOVA on the qualitative analysis of antibacterial activity of methanol extracted finished fabric using *Musa acuminata* leaves.

	Statistical parameters					
Observation	Sum of square	Degrees of freedom	Mean square	F	P	F-critical
Between the samples	5. 05	2	2. 52	91	0. 000462	6. 94
Error	0. 72	2	0. 36	13	0. 017778	6. 94
Total	0. 11	4	0. 02			
	5. 88	8				

Table 7. Two-way ANOVA on the quantitative analysis of antibacterial activity of methanol extracted finished fabric using *Musa acuminata* leaves.

	Statistical parameters					
Observation	Sum of square	Degrees of freedom	Mean square	F	P	F-critical
Between the samples	37. 6	2	18. 80	179. 70	0. 000121	6. 94
Error	136. 06	2	68. 03	649. 97	9. 41E-06	6. 94
Total	0. 41	4	0. 10			
	174. 09	8				

Table 8. Two-way ANOVA on the ultraviolet radiation protection factor of methanol extracted finished fabric using *Musa acuminata* leaves.

		Statistical parameters					
Property	Observation	Sum of square	Degrees of freedom	Mean square	F	P	F-critical
Whiteness index (D65-10)	Between the samples	11963. 8	3	3987. 94	69220. 1	9. 3E-08	9. 27
	Error	0. 58861	1	0. 58861	10. 2167	0. 04947	10. 12
	Total	0. 17284	3	0. 05761			
		11964. 6	7				

protection factors, and FTIR. This evaluation helps to determine the clothing protection factor due to the finishing of fabric with methanol extract of *M. acuminata* leaves. The variables such as concentration, temperature, and process timing are considered as very important factor if the probability (p) value is less than 0.05. The results of Two-way Analysis of variance are shown below (Table 6 to 8) for the antibacterial, UV protection factor and FTIR compounds.

From Table 6, 7 and 8, it is observed that the *p*-value for antibacterial properties and UV protection of finished fabric <0.05. This evidence clearly shows that there is a significant dissimilarity in the methanol extraction of *M. acuminata* leaves on the antibacterial and UV protection properties of finished fabric at 95% of confidence level. So, it is summarizing that the treating of specimen with *M. acuminata* methanol extract influences the antibacterial and ultraviolet protection properties of the specimen.

Conclusion

M. acuminata leaf methanol extract contains carbon compounds of the phenol group which binds to proteins in-vitro forming soluble and insoluble complexes. The presence of functional groups will support clothing protection with higher affinity. The present work is limited to antimicrobial activity and ultraviolet protection effect. The antibacterial effect of *M. acuminata* leaf methanol extract finished fabric inhibited the growth of *S. aureus* bacteria only, but it shows an insignificant impact on the growth of *E. coli* bacteria. The zone of inhibition in the treated specimens was wider with respect to *S. aureus*. The zone of inhibition gets wider by increasing the concentration and temperature which is proven in both qualitative (zone of inhibition) and quantitative (percentage of reduction). The finishing of fabric with *M. acuminata* leaf influences strongly on the UPF value. The ultraviolet protection factor increases in *M. acuminata* leaf methanol extract treated fabric than the untreated fabric sample. This is due to the higher absorbance of UV radiation by the treated fabric sample. Hence, it is observed that the *M. acuminata* leaf methanol extract having the capability to control the positive pathogenic bacteria as well have protection from the ultraviolet radiation. The efficiency of the protection level increases by increasing the level of concentration and temperature.

Disclosure statement

No potential conflict of interest was reported by the author(s).

ORCID

C. Prakash http://orcid.org/0000-0003-2472-6765
B. Venkatesh http://orcid.org/0000-0003-4996-0021
S. Sivamani http://orcid.org/0000-0002-8986-9866

References

Adeel, S., F. U. Rehman, M. K. Khosa, S. Rajab, K. M. Zia, M. Zuber, and F. Batool. 2021. Eco-friendly isolation of colorant from Arjun bark for dyeing of bio-mordanted cotton fabric: short title: Dyeing of bio-mordanted cotton with Arjun bark colorant. *Journal of Natural Fibers* 1–12. doi:10.1080/15440478.2020.1870618.

Balakrishnan, S., G. L. D. Wickramasinghe, and U. S. Wijayapala. 2019. Investigation on improving banana fiber fineness for textile application. *Textile Research Journal* 89 (21–22):4398–409. doi:10.1177/0040517519835758.

Felhi, S., A. Daoud, H. Hajlaoui, K. Mnafgui, N. Gharsallah, and A. Kadri. 2017. Solvent extraction effects on phytochemical constituents profiles, antioxidant and antimicrobial activities and functional group analysis of Ecballium elaterium seeds and peels fruits. *Food Science and Technology* 37 (3):483–92. doi:10.1590/1678-457X.23516.

Gao, Y., and R. Cranston. 2008. Recent advances in antimicrobial treatments of textiles. *Textile Research Journal* 78 (1):60–72. doi:10.1177/0040517507082332.

Geethu, M. G., P. S. Suchithra, C. H. Kavitha, J. M. Aswathy, B. Dinesh, and K. Murugan. 2014. Fourier-transform infrared spectroscopy analysis of different solvent extracts of water hyacinth (*Eichhornia crassipes Mart Solms*.) an allelopathic approach. *World Journal of Pharmacy and Pharmaceutical Sciences* 3 (6):1256–66.

González-Montelongo, R., M. G. Lobo, and M. González. 2010. The effect of extraction temperature, time and number of steps on the antioxidant capacity of methanolic banana peel extracts. *Separation and Purification Technology* 71 (3):347–55. doi:10.1016/j.seppur.2009.12.022.

Gupta, V., D. Chaudhary, S. Gupta, and N. Yadav. 2017. Environment friendly antibacterial and UV protective finish on cotton using *Syzygium cumini* (L.) leaves extract. *International Journal of Textile and Fashion Technology* 7 (1):53–62.

Harris, L. G., S. J. Foster, and R. G. Richards. 2002. An introduction to Staphylococcus aureus, and techniques for identifying and quantifying S. aureus adhesions in relation to adhesion to biomaterials: Review. *European Cell and Material* 4:39–60. doi:10.22203/ecm.v004a04.

Jaswal, P., S. AgyaPreet, and G. Goel. 2017. Antimicrobial activity of herbal treated cotton fabric. *International Research Journal of Engineering and Technology* 4 (8):39–43.

Kumar, P. R., S. Srivastava, K. K. Singh, C. Mathad, and P. S. Thin. 2014. Study of antioxidant and antimicrobial properties, Phytochemical screening and analysis of sap extracted from Banana (*Musa acuminata*) pseudostem. *International Journal of Advanced Biotechnology and Research* 5 (4):649–58.

Mathew, N. S., and P. S. Negi. 2017. Traditional uses, phytochemistry and pharmacology of wild banana (*Musa acuminata* Colla): A review. *Journal of Ethnopharmacology* 196:124–40. doi:10.1016/j.jep.2016.12.009.

Mothilal, B., C. Prakash, V. Ramesh Babu, C. Ganapathy, and S. Sivamani. 2020. Investigation on the application of *Musa acuminata* leaf methanol extract on cellulose fabric. *Journal of Natural Fibers* 17 (1):132–39. doi:10.1080/15440478.2018.1470058.

Pachiayappan, K. M., C. Prakash, and V. Kumar. 2020. Influence of process variables on antimicrobial properties of cotton knitted fabrics. *Journal of Natural Fibers* 17 (3):313–25. doi:10.1080/15440478.2018.1492487.

Prakash, C., A. JebastinRajwin, S. Periyasamy, and G. Gunasekaran. 2021. Effect of Bamboo and neem charcoal micro particles application on the Anti Bacterial and UV protection properties of woven fabrics. *The Journal of the Textile Institute* 112 (7):1171–80. doi:10.1080/00405000.2020.1805193.

Ramesh, P., C. Prakash, N. K. Palaniswamy, N. Sukumar, and S. Sengottuvelu. 2017. Evaluation of antibacterial efficacy and wound healing activity of natural fibre based wound dressing coated with natural extracts of calotropis *gigantean, eucalyptus globules* and buds of *Syzygium aromaticum* enhanced with epidermal growth factor. *International Research Journal of Pharmacy* 8 (5):95–100. doi:10.7897/2230-8407.08581.

Rathinamoorthy, R., G. Thilagavathi, S. Brindha, P. Gayathri, N. S. Poornakala, and B. Pradeep. 2014. Odour control studies on apparel fabrics finished with methanol extract of Terminalia chebula. *Fibers and Polymers* 15 (8):1669–76. doi:10.1007/s12221-014-1669-7.

Sango, T., A. M. C. Yona, L. Duchatel, A. Marin, M. K. Ndikontar, N. Joly, and J. M. Lefebvre. 2018. Step–wise multi–scale deconstruction of banana pseudo–stem (*Musa acuminata*) biomass and morpho–mechanical characterization of extracted long fibres for sustainable applications. *Industrial Crops and Products* 122:657–68. doi:10.1016/j.indcrop.2018.06.050.

Szostak-Kotowa, J. 2004. Biodeterioration of Textiles. *International Biodeterioration & Biodegradation* 53 (3):165–70. doi:10.1016/S0964-8305(03)00090-8.

Torti, S. D., M. D. Dearing, and T. A. Kursar. 1995. Extraction of phenolic compounds from fresh leaves: A comparison of methods. *Journal of Chemical Ecology* 21 (2):117–25. doi:10.1007/BF02036646.