Tec Empresarial
P-ISSN: 1659-2395; E-ISSN: 1659-3359

INVESTIGATION OF UV PROTECTIVE COTTON FABRIC DYED WITH POMEGRANATE PEEL EXTRACT

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Abstract:
The antibacterial effects of cotton fabric coloured with pomegranate peel extract are examined in this study. It evaluates the fabric's performance in relation to *Aspergillus Flavus*, Gram-positive - *Escherichia coli* & Gram-negative - *Staphylococcus aureus* microorganisms. Due to the increased abundance of dye molecules, the results demonstrate that fabric dyed at pH 7 with a % dye concentration demonstrates the highest antibacterial and antifungal activity. Additionally, the article assesses the colour strength (K/S) of the fabric dyed with pomegranate peel & provides CIE lab coordinates to quantify colour properties. The fabric's liquid moisture management properties, crucial for wound dressing materials, are also assessed, showing excellent wetting, absorption, and spreading characteristics. The Ultra Protection Factor (UPF), which measures how well the fabric filters out UV rays, is also examined in the study. It is discovered that adding pomegranate peel extract dramatically increases the UPF from 12 to 45. The potential for cotton fabric coloured with pomegranate peel to provide effective UV protection is highlighted by this development.
Keywords: Antibacterial, Fabric, Moisture, Natural dye, Ultraviolet protection

Introduction

The use of natural colours has recently undergone a significant change in the textile sector. The leading cause behind this trend is the increasing awareness of how important for sustainability and environmental friendliness (Khan et. al., 2011). Fabric has been produced using the tradition dying, which has been practiced since the beginning of time. However, following the introduction of synthetic dyes in 1856, the decline in the utilization of organic colours was initiated as synthetic dyes gained in popularity. (Swami et. al., 2012). Synthetic dyes were firstly used in the textile industry, but they also showed concerns about possible health effects on people, including skin allergies, skin conditions, and even cancer. Thus, an increasing number of researches started looking for alternatives, finally concentrating on naturally available colours made from organic ingredients, which present a safer and more environmentally friendly substitute (Kulkarni et. al., 2011).

The utilization of natural dyes, sourced from a variety of origins including plants, minerals & animals, is an ancient tradition that is employed for a wide range of applications, from food extracts and pharmaceuticals to textiles and leather (Geelani et al. of 2015). Numerous researchers report various societies have engaged natural dyes for last decades. For instance, in ancient Egypt, indigo-dyed fabrics were utilized to wrap and preserve mummies, featuring the deep-rooted the past of natural dye application (Patel et. al., 2013). Natural dyes have also convened a prominent place in the territory of art, as evidenced by the vibrant concepts of ancient Indian art collections like Warli, Madhubani, Patachitra, Pithora, and Phad. These artworks derived their colours from a various source including fruits, leaves, flowers, seeds, barks, roots, and insects.

Synthetic dyes, including allergies and potential carcinogenicity, have prompted a reassessment of the use of botanical or eco-friendly dyes in textile coloring applications (Frose et. al., 2019 & Chung et. al., 2016). In addition, the environmental ramifications of synthetic dyes, including the contamination of water and soil by up to 15% of unfixed dye, have emphasized the ecological benefits of natural dyes (Chan Chao et. al., 2017). Now a days, ecological concerns are of primary importance, the environmentally friendly and non-allergenic nature of natural dyeing processes has achieved significance (Boominatha et. al., 2020). The synthetic dyeing processes have been concerned in advancing harmful bacterial growth in the environment, leading to issues such as discoloration, unpleasant odours, and allergic reactions in users (Gupta et.al., 2004). Therefore, there has been an increasing focus on integrating antimicrobial textile finishing techniques to elevate the overall quality of textiles. (Kamboj et. al., 2021). Natural dyes sourced from plants are imbued with phenolic chemicals, which confer inherent antibacterial and anti-inflammatory properties, further highlighting their suitability for textile applications (Kamboj et. al., 2021). Moreover, many plant extracts used as natural dyes have demonstrated medicinal properties (Ali et. al., 2009).

The integration of natural plant extracts as colorants not only fulfils the aesthetic requirement for vibrant hues but also introduces antimicrobial properties to textiles. Several scientific studies have demonstrated the superior antimicrobial activity of plant extracts obtained from sources such as Curcuma longa, Punica granatum, Acacia catechu, and pomegranate shells (Naveed, et. al., 2020; Rajendran et. al., 2011). Furthermore, the concept of colour fastness, denoting a material's resistance to colour change and the transfer of colorants to adjacent materials, is of paramount importance in textile fibres (Samanta and Agarwal, 2009). The growing market demand for naturally dyed products underscores the need for natural dye manufacturers to produce larger quantities of consistent shades with high fastness properties. This necessitates the standardization of technologies and the adoption of natural dyeing systems. Thus, a comprehensive scientific understanding of the production of reproducible natural textile coloration, encompassing the role of mordanting agents, dyeing conditions, and the medical properties of resulting fabrics, becomes imperative. The current research endeavour seeks to explore the dyeing process with a rigorous scientific approach, with a focus on achieving superior colour strength and antimicrobial qualities on cotton fabric through natural dyeing techniques.

Materials and Methods

Preparing Pomegranate Peel for Dye Extraction

Pomegranate peel samples were collected from juice shops, cleaned, and dried. They were then ground into fine powder and sieved to obtain consistent 2 mm particles. This powder was used for dye extraction. We used chemicals like sodium hydroxide, sodium carbonate, distilled water, ethanol, salt, acetic acid, and detergents.

The process of extracting the coloring components from the pomegranate peels involved the use the Soxhlet extraction method with ethanol as a solvent to extract color components from the pomegranate peel. The peel and ethanol were mixed, heated, and the extract was collected after several hours of extraction. After extraction, ethyl acetate was added to separate the natural dye from unwanted substances.

Dyeing Cotton Fabric

The dye that exhibited the highest extraction efficiency was used to dye bleached cotton fabric using the following dyeing parameters: a tem of 70°C, a dyeing duration of 30 mins, a material-to-liquid ratio of 1:10, & a salt concentration of 30 grams per litter, which also incorporated 10% sodium carbonate.

Color Analysis

After dyeing, we assessed the color intensity of the fabric by employing a spectrophotometer and the CIELAB color space. The CIELAB space includes DL* (color lightness), Da* (redness-greenness), and Db* (yellow-blue), with defined limits for each.

Antibacterial Test

To evaluate the fabric's antibacterial qualities after dyeing with pomegranate peel extract, a set of standardized tests is used. These tests are essential for determining how well the dyed fabric inhibits bacterial development. The magnitude of the zones of inhibition is used to gauge the pomegranate peel dyed fabric's antibacterial effectiveness. Stronger antibacterial action is indicated by a bigger zone. If the cloth significantly inhibits bacterial growth when compared to the control samples, it has antibacterial qualities.

UV Testing

According to AATCC 183: 2010, the test method for calculating the Ultra Protection Factor of pomegranate peel dyed fabric entails evaluating the fabric's capacity to give ultraviolet (UV) protection. By calculating the fabric's UVPF value, this is performed (UPF).

Moisture Management behavior

The following test procedures are used to evaluate how pomegranate peel-dyed fabric regulates moisture:

Absorbency Test: The measurement of how rapidly a water droplet is absorbed is used to assess the fabric's moisture absorption capacity.

Wicking Test: Measuring the vertical distance liquid travels in a predetermined amount of time to determine how quickly moisture distributes through the cloth.

Moisture Retention Test: Determining how well the fabric retains moisture by weighing it before and after exposure to moisture.

Result and Discussion

Colour Strength of pomegranate peel dyed fabric

A spectrophotometer measures the color intensity (K/S value) of the dyed fabrics. The results are tabulated in Table 2 and encompass the CIE Lab coordinates for the following parameters: L*, indicating brightness; a*, denoting redness-greenness; b*, indicating yellowness-blueness; c*, representing chroma or saturation; and h, denoting hue angle values. In accordance with the CIE L* a* b* color space, the dyed cotton sample from 1% concentration of dyestuff is green, which is reflected in a (-) and yellow in b* (+). The redness of the dyed cotton sample produced by 5% dyestuff concentration was reflected in a* and b*. In comparison to the values obtained from 1% concentration and 5% concentration, the value of a* (redness) in coloured cotton fabric is higher for 5%.

Table 1 Colour Strength of pomegranate peel dyed fabric

S. No.	Pomegranate Peel Dyeing Method				L^*	a^*	b^*	C^*	h	Sample Picture
	pH	Con.	Hours	Testing No						
1.	5	1%	12	N2466-4	73.69	8.88	25.75	27. 24	70.98	
2.	5	5%	12	N2466-3	65.76	10.35	29.38	31.15	70.59	
3.	7	1%	12	N2466-2	77.35	2.57	34.88	34.97	85.79	
4.	7	5%	12	N2466-1	69.15	8.09	30.93	31.97	75.33	
5.	9	1%	12	N2466-6	73.37	1.12	36.75	36.77	88.26	
6.	9	5%	12	N2466-5	65.79	5.47	32.76	33.21	80.52	

Antibacterial activity of Pomegranate peel dyed fabric

The antibacterial efficiency of the Pomegranate peel extract treated cotton fabrics was tested against wound infecting pathogens and their ZOI (Zone of inhibition) values are presented in table 2.

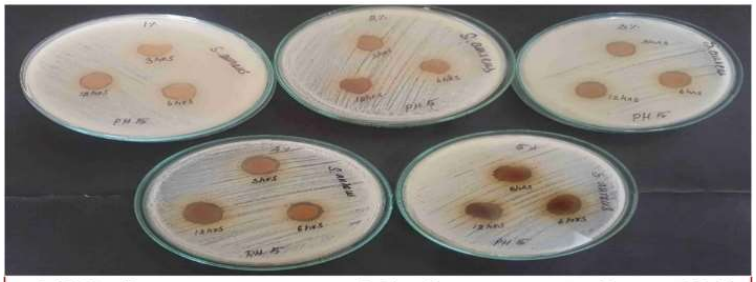
Table 2 Antibacterial activity of Pomegranate peel dyed Cotton fabric

pH Value	Dye Concentration	ZoI against Gram Positive (Staphylococcus aureus)		
		Time duration		
		3 Hours	6 Hours	12 Hours
pH 5	1%	11	13	14
	2%	12	13	15
	3%	15	16	17

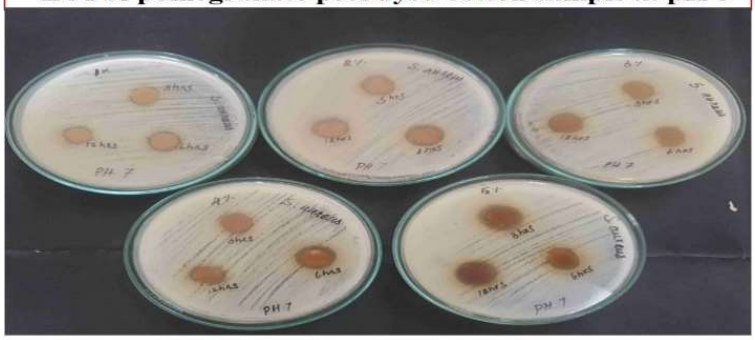
	4%	15	16	17
	5%	16	17	18
pH 7	1%	12	15	14
	2%	15	16	17
	3%	14	17	17
	4%	13	17	18
	5%	15	19	18
pH 9	1%	-	-	-
	2%	-	-	-
	3%	-	-	-
	4%	-	-	-
	5%	-	-	-

Table 2 displays the antibacterial performance of cotton fabric dyed using pomegranate peel dye. This characterization was conducted following the SN 195 920-1992 standard. The analysis reveals that samples prepared at pH 7 demonstrate enhanced antibacterial properties against Gram-positive bacteria - *S.aureus*. In most of the samples this trend was found. More specifically the sample prepared with pH 7 and dye concentration 5% were shown highest antimicrobial activity (ZOI of 19 in 6 hours period). It was also interpreted that the dyed samples with pH 9 have not shown any of the antimicrobial activity in different time period. Through this investigation it was confirmed that the dyed sample at pH 7 has responded effectively and dye concentration 5% has yielded better antimicrobial activity which is interpreted that due to higher dye concentration the availability of dye molecules are quit high

Than low concentrated sample. The figure 1 has shown the ZOI against *Staphylococcus aureus* in different pH and dye concentration.



ZOI of pomegranate peel dyed cotton sample at pH 5



ZOI of pomegranate peel dyed cotton sample at pH 7

ZOI of pomegranate peel dyed cotton sample at pH 9

Figure 1 Antibacterial activity of pomegranate peel dyed fabric against *S.aureus*

Liquid moisture management test results of selected pomegranate peel dyed cotton fabric

Liquid moisture management properties of the selected pomegranate peel dyed cotton fabric results are displayed in the table 3.

Table 3 Moisture Management behavior of pomegranate peel dyed cotton fabric

	Wetting time (sec)		Absorption rate (%/sec)		Maximum wetted radius (mm)		Spreading speed (mm/sec)		One way Transport Capability	OMMC
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom		
Mean	3.8376	3.5382	10.2029	46.9858	21	24	4.3131	4.638	390.9693	0.8122
S.D	1.8344	1.7903	4.2227	9.6282	4.1833	2.2361	1.0145	0.923	50.0469	0.056
Grade	4.6	4.7	1.3	3.3	4.2	4.8	4.6	4.7	4.6	4.8

OMMC Grades: 0 - 0.2: Very much not strong

0.2 - 0.4: Not strong

0.4 -0.6: Strong

0.6 -0.8: Very strong

0.8>: Excellent

Liquid mo

Index	**Unit**	**Grading of the indices Pomegranate peel dyed cotton fabric**
Wetting time top surface - WTt	sec	Very fast - < 3
Wetting time bottom surface - WTb		Very fast - < 3
Absorption rate top surface - ARt	% / sec	Slow (10-30)
Absorption rate bottom surface - ARb		Medium (30-50)
Maximum wetted radius top surface	mm	Large (17-22)
Maximum wetted radius bottom surface		Very large (>22)
Spreading speed top surface - SSt	mm / s	Very fast - >4
Spreading speed bottom surface - SSb		Very fast - >4
Accumulative one-way transport index -R	%	Very good (200-400)
Overall moisture management capacity - OMMC	-	Excellent - >0.8

The table 3 carries the two values, namely; the grade values for the pomegranate peel dyed selected fabric and their moisture management behaviors. The specified indices described these values, Yao *et al*., (2006). It is a common occurrence and a primary concern that wound dressing materials should possess effective management of liquid moisture properties. The results have confirmed that the pomegranate peel-dyed fabric selected for this study possesses moisture management properties with different index gradings. These characteristics encompass moderate to swift wetting, moderate to rapid absorption, a generous coverage area on the lower surface, swift expansion on the underside, and align with the criteria outlined by Yao et al. (2006) as essential attributes for effective one-way transport.

Wetting time (medium to fast wetting)

Index values, for the pomegranate peel dyed fabric, are more than the essential level. The selected fabrics dyed with pomegranate peel displayed an extremely rapid wetting time on both the top and bottom surfaces.

Absorption rate of top surface (Medium to fast absorption)

The required grade for the absorption percentage is medium to fast absorption. The pomegranate peel dyed fabric showed the slow index value at the top absorption percentage and it is medium for the bottom surface.

Maximum wetted radius bottom surface (Large spread area at bottom surface)

The grade value for the maximum wetted radius was expected as large area for the moisture management fabric. The pomegranate peel dyed fabric showed exceptionally the required standard high wetting radius with grade indices of very large.

Spreading speed bottom surface (Fast spreading at bottom surface)

The pomegranate peel dyed fabric approve very fast grade indices and it was more than the predicted standard.

Accumulative one-way transport index (Good to excellent one –way transport)

The test results demonstrate that the fabric dyed with pomegranate peel exhibited a highly favorable one-way transport index. The pomegranate peel dyed fabric showed 200-400 AOTI with very good grade. Therefore, from the above shown table 4 it was concluded that the pomegranate peel dyed fabric obtained good to excellent grade and indices for the entire index achieved.

Ultra protection factor of the finished Fabric

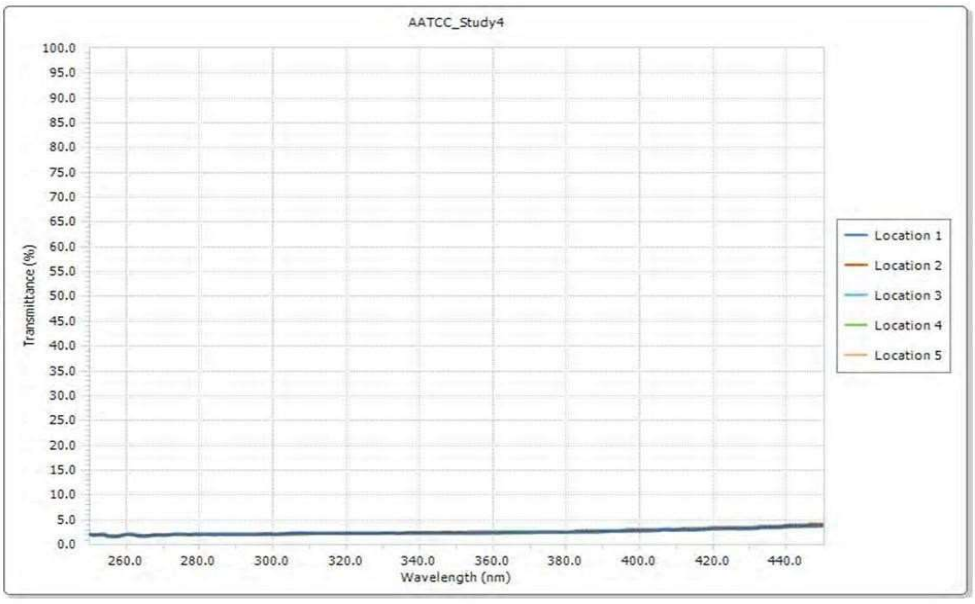


Figure: 2 UPF rating for treated sample

From the above-mentioned figure 2, it is discovered that the rating for the untreated fabric in UPF is 12 while for the treated fabric is 45. Furthermore, UPF rating for the treated sample fabric exposes an exceptional protection against UV rays (UPF 45 rating) but on the other hand, the

untreated sample fabric exhibits the impoverished protection against UV rays (UPF 12 rating). Here it can be wound up that the detrimental effects of UV rays and their protection against them preserved textile material by using Pomegranate peel in the cotton fabric (figure 2) accordingly.

Conclusion

In this study, we conducted a comprehensive examination of the antimicrobial properties of cotton fabric treated with pomegranate peel extract. Our investigation centered on assessing the fabric's efficacy against both *S. aureus* (Gram-positive bacteria) and *E. coli* (Gram-negative bacteria), as well as its antifungal activity against Aspergillus Flavus. The results indicated that fabric dyed at pH 7 with a 5% dye concentration exhibited the highest levels of antimicrobial and antifungal activities. This remarkable performance can be attributed to the greater availability of dye molecules in this particular configuration.

Additionally, our study entailed a comprehensive analysis of the color strength (K/S) in pomegranate peel-dyed fabric, culminating in the determination of its color characteristics through CIE Lab coordinates. The outcomes revealed noticeable shifts in color attributes, including lightness (L*), redness-greenness (a*), and yellowness-blueness (b*). Notably, fabrics dyed at a 5% concentration exhibited heightened redness values (a*) compared to those dyed at a 1% concentration, signifying a more profound hue.

The fabric's capacity to regulate liquid moisture was also examined because it's crucial for applications like wound dressings. Our research revealed that the pomegranate peel-dyed fabric displayed good wetting, absorption, and spreading characteristics in accordance with the requirements for effective moisture management. Our work examined the fabric's UV-protective properties in addition to its antibacterial and moisture-management properties. Following treatment, the Ultra Protection Factor (UPF), which was given pomegranate peel extract, considerably increased, going from 12 to 45. The fabric's potential to provide effective UV protection is highlighted by this noteworthy advancement, making it a valuable choice for applications requiring sun-blocking materials.

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