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AN ANALYTICAL STUDY POMEGRANATE PEEL EXTRACT DYED COTTON FABRICS FOR ULTRAVIOLET PROTECTION

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Abstract:
The aim of the study is to investigated the antibacterial properties of dyed cotton fabrics with pomegranate peel extract. It was noted that the effectiveness of this substance was studied against both Gram-positive bacteria (*Staphylococcus aureus*) and Gram-negative bacteria (*Escherichia coli*). Furthermore, antifungal effects against Aspergillus flavus were also confirmed. Ultimately, the results showed that fabrics dyed at pH 7 and dye concentration of 5% had the highest antibacterial and antifungal activity. These activities can be attributed to the accessibility of the dye molecules. Moreover, this article provides his CIE laboratory report to measure the color strength (K/S) of fabric dyed with pomegranate peel and harmonize and explain the color characteristics. The next factor, namely H. The texture of the liquefied water is important and also determines the tissue and wound dressing management properties. This product has excellent wetting, absorption and dispersion properties. Additionally, this study investigated the protection of fabrics against UV radiation and showed a significant increase in Ultra Protection Factor (UPF) from 12 to 45 after analysis using pomegranate peel extract. The complete thermogravimetric residues of different pomegranate peel extract concentrations at different pH values are shown. The given graph clearly shows that 1% pomegranate peel extract has the least residue than other ingredients. Moreover, the maximum residue is observed at a concentration of 2% pomegranate peel extract, which is more thermally stable than other materials. This reinforcement highlights the potential of pomegranate peel-dyed cotton fabrics to provide strong UV protection.

Keywords: Antibacterial, Fabric, Moisture, Natural dye, Ultraviolet protection, Thermogravimetric.

Introduction

In contemporary measure, there has been an identifiable transfer in the textile industrywith regard to an enlarged usage of natural dyes. This transference is mainly designated by a developing awareness of the imperative need for feasibility and eco-friendliness(Khan et al., 2011) . In the process of dyeing, an antiquated property that was anticipated already foreshadows the recorded history and has always been part and parcel of combined surface of fabric production. Nevertheless, the well- known acquisition of synthetic dyes following theirdetermination in 1856 (Samanta and Agarwal, 2009) paved the way to a moderate diminishingin the utilisation of natural dyes. When synthetic dyes gained strong coverage in the textile industry, they generated their concerns with regard their potential inauspicious consequences on human health, including skin allergies, skin diseases, and even cancerous disease. As a consequence, a multiplying number of people began to inspect and investigate alternatives. After a period of time, switching on their attention to natural dyes that derived from organic sources, which also provides a safer and more environmentally friendly and sustainable chances. Thus, they become their customs and part of their deal (Kulkarni et al., 2011).

The extraction of natural dyes from various resources such as plants, minerals, and *animals a*re experimented in laboratory with ancient roots, serving different purposes emerging from textiles and leather materials to feed compounds and medicines (Geelani et al., 2015). The analysis shows that the historical evidence is filled with examples of the long-establisheduse of natural dyes in several civilizations. For example, during Egypt, indigo-dyed fabrics were commissioned to pack and conserve mummies, underscoring the deep-rooted history of natural dye application (Chung, 2016). Right from the centuries, Natural dyes have also held in a distinguished position in the realm of arts as signified by the energetic creations of ancient Indian art collections like Warli, Madhubani, Patachitra, Pithora, and Phad. These kinds of artworks obtained their colors from a manifold array of sources, including flowers, fruits, leaves, seeds, barks, roots, and even insects.

The unfavourable reactions correlated with synthetic dyes, such as their allergenic and carcinogenic belongings have brought about reappraisal of natural dyes for textile coloring resolution (Fröse et al., 2019). Furthermore, the environmental consequences of synthetic dyes, including the water pollution and soil pollution by up to 15% of detached dye components, have underscored the ecological ascendancy of natural dyes (Chao et al., 2017). In contemporary and modern world, where ecological concerns are of greatest importance, the eco-friendly benign and non-allergenic nature of natural dyeing procedures have acquired developing consequences (Boominathan et al., 2022). The process shows that the fabricated, synthetic dyeing processes have been compromised with fostering harmful bacterial development in the surrounding, directing to issue such as discoloration, displeasing odours, and allergic reactions for customers (Gupta et al., 2004). Accordingly, there has been an increasing emphasis on incorporating antimicrobial textile finishing techniques to empower theentire quality of textiles (Kamboj et al., 2022). Natural dyes obtained from natural plants are permeated with phenolic chemicals, which bestow immanent antibacterial and anti- inflammatory properties, advancing to highlight their fitness for textile solicitations (Kamboj etal., 2022). Besides all these, several plant extracts utilised as natural dyes have illustrated medicinal properties, attaching to their interest (Ali et al., 2009).

The amalgamation of natural plant extracts used as colorants not only to establish the aesthetic necessity for vibrant shades but also instigates antimicrobial properties to textiles. Different scientific analytical studies have exemplified the superior antimicrobial activity of plant extracts secured from sources such as Curcuma longa, Punica granatum, Acacia catechu,and pomegranate shells (Naveed et al., 2020). Besides, the concept of colour fastness, designating a material's resistance to colour change and the transfer of colorants to adjacent substances, is of extraordinarily importance in textile fibres(Samanta and Agarwal, 2009) . Thedeveloping market requires for naturally dyed products accentuate the need for natural dye constructors to yield huge quantities of compatible shades with excessive fastness properties. This involves the high similarity of technologies and the endorsement of natural dyeing systems. Thus, a combined scientific understanding of the production of reproducible natural textile coloration, embracing the role of mordanting agents, dyeing conditions, and the medicalproperties of resulting fabrics are the main sources for enhancing trustworthiness. There is chance for this combined study of degradation by TG could be greatly empowered. This could beachieved by a combination of TG along with other techniques that has the capacity to provide either qualitative or both qualitative and quantitative statistics. The current research work undertakes the search to explore the dyeing activity with a meticulous scientific approach with theconcentration in accomplish superior colour strength and antimicrobial qualities on cottonfabric through natural dyeing method.

Materials and Methods

Preparing Pomegranate Peel for Dye Extraction

Pomegranate peel samples were accumulated from local juice shops, cleansed, and dried up. 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 such as, sodium hydroxide, sodium carbonate, distilled water, ethanol, salt, acetic acid, and detergents.

The process of extracting the colouring components from the pomegranate peels involved the use the Soxhlet extraction method with ethanol as a solvent to extract colour components from the pomegranate peel. The peel and ethanol got mixed together, heated, andthe extract was collected after numerous hours of extraction. Once extraction is done, ethyl acetate was blended to segregate the natural dye from unwanted substances.

Dyeing Cotton Fabric

To dye bleached cotton fabric, we employed the most effectively extracted dye under the following dyeing conditions: a temperature of 70°C, a dyeing time of 30 minutes, a materialto liquid ratio of 1:10, and a salt concentration of 30g/L, which also included 10% sodium carbonate.

Colour Analysis

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

Antibacterial Test

To examine the antibacterial activity of dyed fabric with pomegranate peel extract, a series of standardized tests are engaged. These tests are performed crucially in determining the effectiveness of the dyed fabric in inhibiting the growth of bacteria**.** The antibacterial activity of the pomegranate peel dyed fabric is evaluated basing on the size of the zones of inhibition. A larger zone indicates stronger antibacterial activity. The fabric is reviewed to have antibacterial properties if it demonstrates a significant inhibition of bacterial growth comparedto the control samples.

Thermogravimetric analysis

The popped up cheaper, faster, user friendly for determining the composition of lignocellulosic biomass is Thermogravimetric analysis (TGA).. TGA can also be used as a more accurate method to measure α-cellulose and hemicellulose compared to commonly used wet chemical methods.

Analysis of ultraviolet protection factor

Here, we use the UV Protection Factor (UPF) to evaluate the UV protection of fabrics. UPF tests and analyzes the reduction in the amount of ultraviolet light that penetrates tissues and reaches the base of the skin. A more precise example here would serve the purpose better. If a fabric has a UPF of 20, only 1/20th of the UV rays will reach the skin's surface. The UV transmittance of the fabric samples was analyzed in the wavelength range of 280–400 mm using a Shimadzu UV/Vis spectrophotometer. (The standard method used here to determine UPF was AATCC 183-2010).

Moisture Management behavior

The test methods for assessing the moisture regulative behaviour of pomegranate peel-dyed fabric involve:

Absorbency Test: Measuring the fabric's ability to sponge up the moisture by assessing the time intakes for a drop of water to be blotted up.

Wicking Test: Evaluating how quickly moisture proliferates through the fabric by measuringthe distance moisture travels vertically in a set time.

Moisture Retention Test: considering how well the fabric keeps hold of moisture by weighingit before and after exposure to moisture.

Result and Discussion

1. Colour Strength of pomegranate peel dyed fabric

The spectrophotometer was utilised to calculate the colour strength (K/S) of all the dyedfabrics. The results are systemized from 2 and comprise the CIE lab coordinates for L*, whichdesignates lightness, a*, which indicates redness-greenness, b*, which denotes yellowness- blueness, c*, which distinguishes chroma or saturation, and h, which denotes hue angle values.According to the CIE L* a* b* colour space, the dyed cotton sample from 1% concentration ofdyestuff is green,

which is indicated in a (-) and yellow in b* (+). The redness of the dyed cotton sample is manufactured by 5% dyestuff concentration was reflected in a* and b*. In comparison to the values acquired from 1% concentration and 5% concentration, the value of a* (redness) in coloured cotton fabric is inflated 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	

2. Antibacterial activity of Pomegranate peel dyed fabric

After antibacterial efficiency of the Pomegranate peel extract treated cotton fabrics was tested against wound infecting pathogens and their ZOI values are presented in table 2

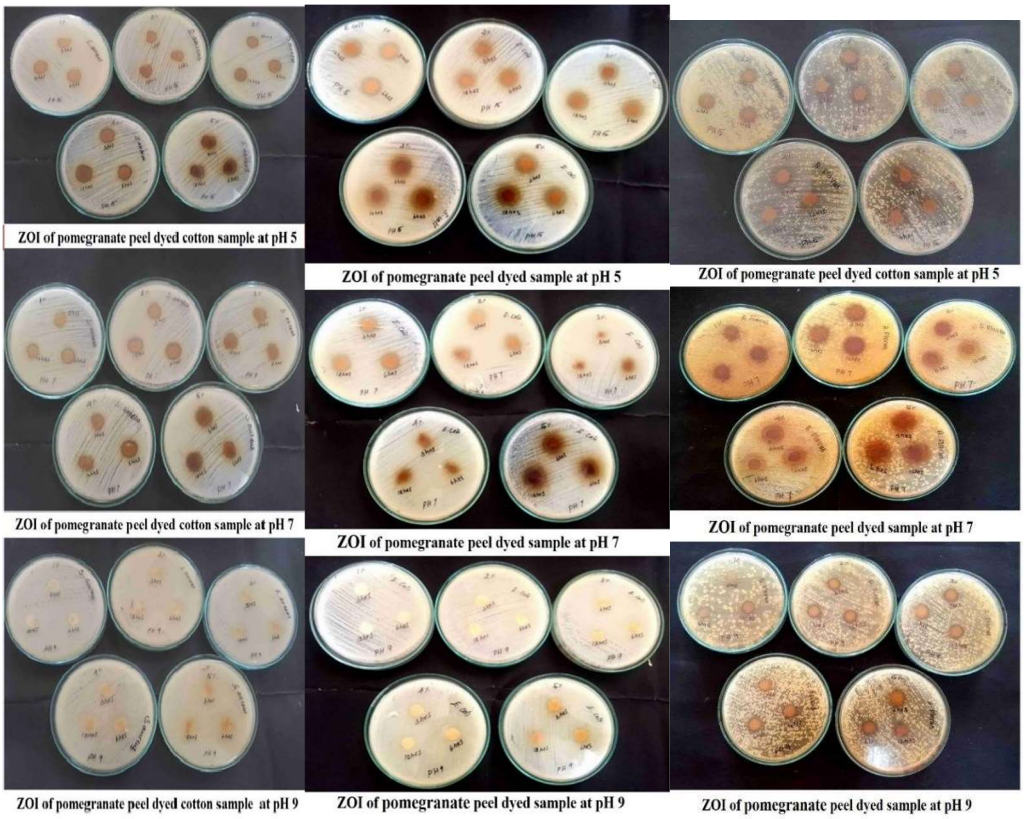
Table 2 Antibacterial activity of Pomegranate peel dyed Cotton fabric

S.No	PH	Dye Con	Duration	(S.aureus)	(E. Coli)	(A.Flavus)
S1	5	1%	3	11	`16	13
S2	5	1%	6	13	19	17
S3	5	1%	12	14	**19**	15
S4	5	2%	3	12	11	17
S5	5	2%	6	13	**17**	20
S6	5	2%	12	15	16	18
S7	5	3%	3	15	17	17
S8	5	3%	6	16	18	20
S9	5	3%	12	17	**17**	18
S10	5	4%	3	16	**15**	**21**
S11	5	4%	6	17	18	22
S12	5	4%	12	18	17	19
S13	5	5%	3	12	17	22
S14	5	5%	6	15	20	23

S15	5	5%	12	14	16	20
S16	7	1%	3	12	10	16
S17	7	1%	6	15	14	16
S18	7	1%	12	14	**13**	19
S19	7	2%	3	15	10	20
S20	7	2%	6	16	**13**	22
S21	7	2%	12	17	12	21
S22	7	3%	3	14	11	17
S23	7	3%	6	17	17	20
S24	7	3%	12	17	**16**	18
S25	7	4%	3	13	17	**18**
S26	7	4%	6	17	18	22
S27	7	4%	12	18	17	19
S28	7	5%	3	15	18	20
S29	7	5%	6	19	23	24
S30	7	5%	12	18	20	23
S31	9	1%	3	3	3	3
S32	9	1%	6	2	2	4
S33	9	1%	12	1	1	3
S34	9	2%	3	2	2	10
S35	9	2%	6	2	2	12
S36	9	2%	12	3	3	10
S37	9	3%	3	1	1	2
S38	9	3%	6	2	3	3
S39	9	3%	12	3	2	2
S40	9	4%	3	1	1	**7**
S41	9	4%	6	2	2	9
S42	9	4%	12	1	2	7
S43	9	5%	3	1	3	7
S44	9	5%	6	2	1	13
S45	9	5%	12	1	2	12

Table 2 indicates that the antimicrobial activity of cotton fabric dyed with pomegranatepeel dye. This characterization is done as per SN 195 920-1992. Through this analysis it is interpreted that the samples prepared through pH 7 have shown higher antimicrobial activity against Gram Positive, Gram Negative and Anti-fungal bacteria (*Staphylococcus aureus, E. Coli, Aspergillus Flavus*). In most of the samples, this trend was found. Taking into account allthese three analyses, the result shows that the same value is found irrespectively in all. More specifically the sample prepared with pH 7 and dye concentration 5% were shown highest antimicrobial activity (ZOI of

19 in 6 hours period). In the same way, it is also elucidated thatthe dyed specimen with pH 9 has conveyed some of the Gram Positive, Gram Negative and Anti-fungal bacteria in contrasting time span. Through this investigation, it was confirmed thatthe dyed sample at pH 7 has responded effectively and dye concentration 5% has yielded betterantimicrobial activity which is interpreted that due to higher dye concentration the availabilityof dye molecules is quite high. The figure:1 has shown the ZOI against *Staphylococcus aureus, E. Coli, Aspergillus* Flavus in different pH level



and dye concentration.

Figure 1 Antibacterial activity of pomegranate peel dyed fabric against S.aureus, E.Coli, Aspergillus Flavus

3. Thermal properties of untreated and treated cotton

The Fig 2a and 2b show both the untreated and treated cotton thermo grams. This resultreveals the two stages of degradation have been observed. First stage reveals at 30°C – 100 °C and the weight loss secured is 1.94%. It is due to loss of moisture present in the cellulose structure.

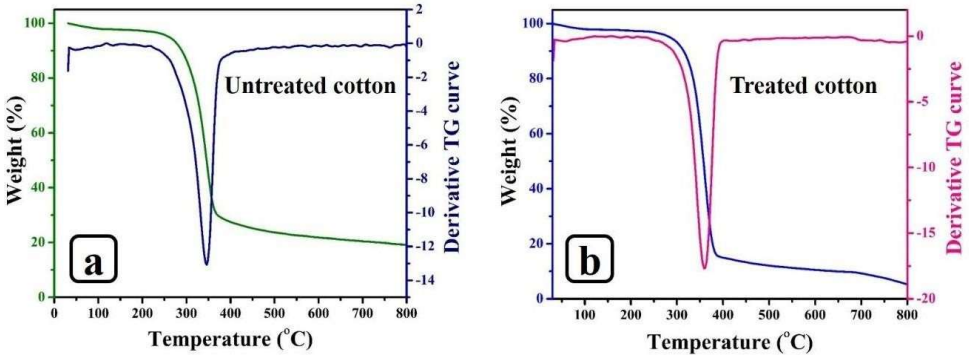


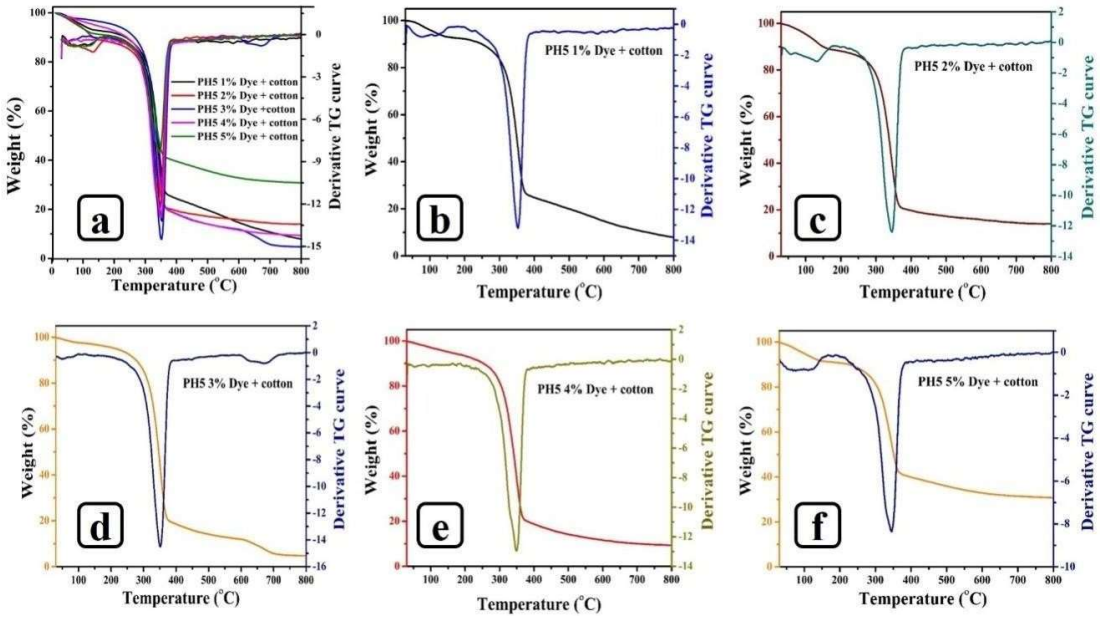
Fig. 2. Thermo gram of a) untreated and b) treated cotton

The second stage degradation happens at temperature 100°C – 800°C and the weight loss as 78.82% which corresponds to cellulose backbone of the molecule. The overall festering of the weight loss is 80.76% and the remaining residue is valued as 19.24% which may contain impurities present in the untreated cellulose (cotton). In the same way, the treated cotton has been observed at same temperature the first stage (30 – 100 °C) degradation observed weight of 2.02% due to loss of moisture present in the treated cotton and the second stage (100 – 800 °C) degradation observed the weight of 92.66% due to loss of cellulose backbone as well. The overall decomposition of 94.68%, that is higher than the untreated cotton. This may affirm the after treatment of cotton 13.92% impurities was removed which is readily to coordinate with the pomegranate peel extract.

3.1 Thermo gravimetric analysis of various pomegranate extract concentration (1 - 5%) + Cotton (PH5)

The overall thermo gram of various concentrations, i.e., 1% to 5%) pomegranate peel extract at PH5 are displayed in Fig. 3a and Fig. 3b – 5f reveals separate thermo gram of 1% - 5% (pomegranate peel extract + cotton). The decomposition values (%) are calculated in Table 3.

Fig. 3. Thermogravimetric analysis of various pomegranate extract concentration(1 - 5%) + Cotton (PH5)



The first stage weight loss observed at 30°C – 100 °C and the decomposition of 3.88, 4.61, 2.31, 2.90 and 4.94% due to loss of moisture present in the cotton of 1%, 2%, 3%, 4% and 5% of pomegranate peel extract adsorbed cotton respectively. The second stage degradation observed at temperature range between 100 – 300 °C and weight loss observed of 12.50, 17.17, 12.28,15.39 and 13.44% because of the decomposition of dye molecule present in the cotton and cellulose structure decomposition begins in the particular temperature range of 1%, 2%, 3%, 4% and 5%of pomegranate peel extract adsorbed cotton.

Table 3: The decomposition values of (PH5) at various pomegranate extract (1 – 5%)

S. No	Dye Concentration (%)	Temperature°(C)			Total Weight Loss (%)	Residue (%)
		Weight loss (%)				
		30 – 100°(C)	100 – 300°(C)	300 – 800°(C)	30 – 800° (C)	
1	1	3.88	12.50	75.67	92.05	7.95
2	2	4.61	17.17	64.15	85.93	14.07
3	3	2.31	12.28	80.64	95.23	4.77
4	4	2.90	15.39	72.40	90.69	9.31
5	5	4.94	13.44	50.67	69.05	30.95

The third stage degradation happens at temperature from 300°C – 800 °C and weight loss observed of 75.67, 64.15, 80.64, 72.40 and 50.67% due to absolute decomposition of cellulose backbone skeleton and dye molecule present in the various concentrations of 1, 2, 3, 4 and 5% pomegranate peel extract adsorbed cotton. The overall decomposition obtained at temperature 30°C – 800 °C

and weight loss observed of 92.05, 85.93, 95.23 and 90.69% with respect to 1, 2, 3, 4 and 5% pomegranate peel extract adsorbed cotton. The highest decomposition observed of 95.23% in 3% pomegranate peel extract adsorbed cotton, which is thermally unsteady than the others material. The highest residue observed 30.95% in 5% of pomegranate peel extract adsorbed cotton which thermally steadier than the other pomegranatepeel extract adsorbed cotton.

3.2 Thermo gravimetric analysis of various pomegranate extract concentration (1 - 5%) + Cotton (PH7)

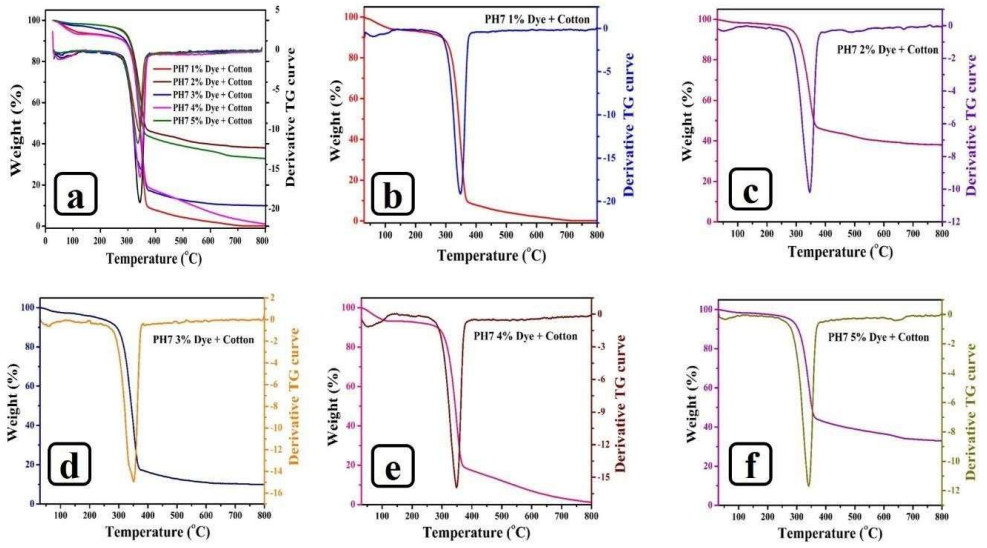


Fig. 4. Thermo gravimetric analysis of various pomegranate extractconcentration (1 - 5%) + Cotton (PH7)

The overall thermo gram of several concentration (1 – 5%) pomegranate peel extract atPH7 are shown in Fig. 4a and Fig. 4b – 4f exhibits individual thermo gram of 1% - 5% (pomegranate peel extract + cotton). The decomposition values (%) are tabulated in Table 4.

The first stage weight loss observed at 30 – 100 °C and the decomposition of 4.61, 1.57,2.52, 5.95 and 1.52% due to loss of moisture present in the cotton of 1, 2, 3, 4 and 5% of pomegranate peel extract adsorbed cotton respectively. The second stage degradation happens at temperature 100°C – 300 °C and weight loss as 6.95, 6.14, 9.23, 6.61and 7.07% due to decomposition of dye molecule present in the cotton and cellulose structure decomposition commends in the particular temperature range of 1, 2, 3, 4 and 5% of pomegranatepeel extract adsorbed cotton.

Table 4: The decomposition values of (PH7) at various pomegranates extract (1– 5%)

S.No.	Dye Concentration (%)	Temperature °(C) / Weight loss (%)			Total Weight Loss (%)	Residue(%)
		30 -100°(C)	100–300°(C)	300-800°(C)	30 - 800	
1	1	4.61	6.95	87.85	99.41	0.59

2	2	1.57	6.14	54.18	61.88	38.12
3	3	2.52	9.23	78.27	90.02	9.98
4	4	5.95	6.61	86.26	98.83	1.17
5	5	1.52	7.07	58.46	67.05	32.95

`The third stage degradation happens at temperature from 300 – 800 °C and weight loss observed of 87.85, 54.18, 78.27, 86.26 and 58.46% due to complete decomposition of cellulose backbone skeleton and dye molecule present in the various concentrations of 1, 2, 3, 4 and 5% pomegranate peel extract adsorbed cotton. The comprehensive decomposition acquired at temperature 30 – 800°C and weight loss observed of 99.41, 61.88, 90.02, 98.83 and 67.05% with respect to 1, 2, 3, 4 and 5% pomegranate peel extract adsorbed cotton. The higher most decomposition observed of 99.41% in 1% pomegranate peel extract adsorbed cotton, which is thermally wobbly than the others material. The maximum residue observed 38.12% in 2% of pomegranate peel extract adsorbed cotton which thermally steadier than the other pomegranate peel extract adsorbed cotton.

3.3 Thermo gravimetric analysis of various pomegranate extract concentration (1 - 5%) + Cotton (PH9)

The altogether thermo gram of various concentration (1 – 5%) pomegranate peel extractat PH9 are exhibited in Fig. 5a and Fig. 5b – 5f displays individual thermo gram of 1% - 5%(pomegranate peel extract + cotton). The decomposition values (%) are categorized in Table 5. In the first stage weight loss observed at 30°C – 100 °C and the decomposition of 2.39, 4.91, 2.27, 2.63 and 1.86% on account of the loss of moisture present in the cotton of 1, 2, 3, 4and 5% of pomegranate peel extract adsorbed cotton respectively.

In the second stage degradation observed at temperature range between 100°C – 300°Cand weight loss observed of 25.34, 21.00, 18.00, 21.06 and 21.90% by reason of decomposition of dye molecule present in the cotton and cellulose structure decomposition begins in theparticular temperature range of 1, 2, 3, 4 and 5% of pomegranate peel extract adsorbed cotton

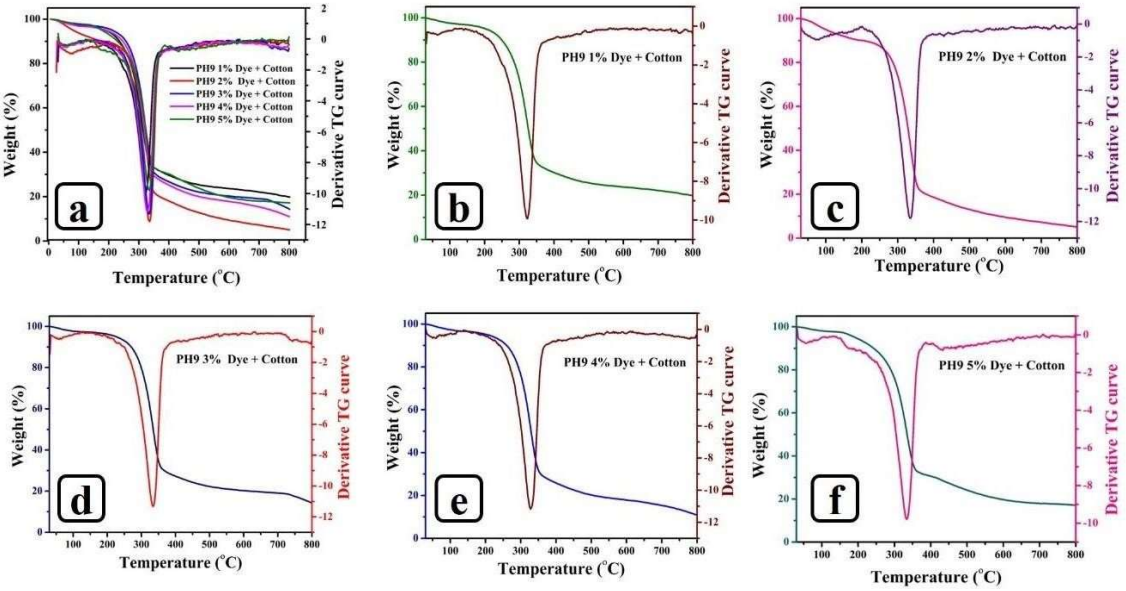


Fig. 5. Thermogravimetric analysis of various pomegranate extract concentration (1 - 5%) + Cotton (PH9)

In the third stage degradation occur at temperature from 300 – 800 °C and weight loss observed of 52.48, 68.98, 65.43, 65.38 and 59.03% in view of completing decomposition of cellulose backbone skeleton and dye molecule present in the various concentration of 1, 2, 3, 4and 5% pomegranate peel extract adsorbed cotton. The inclusive decomposition obtained at temperature 30 – 800 °C and weight loss observed of 80.21, 94.89, 85.70, 89.07 and 82.79% with respect to 1, 2, 3, 4 and 5% pomegranate peel extract adsorbed cotton.

Table 5: The decomposition values of (PH9) at various pomegranate extract (1 – 5%)

S.No.	Dye Concentration (%)	Temperature °(C)				Residue (%)
		Weight loss (%)			Total Weight Loss (%)	
		30 -100 °(C)	100 – 300 °(C)	300 – 800 °(C)	30 - 800	
1	1	2.39	25.34	52.48	80.21	19.79
2	2	4.91	21.00	68.98	94.89	5.11
3	3	2.27	18.00	65.43	85.70	14.30
4	4	2.63	21.06	65.38	89.07	10.93
5	5	1.86	21.90	59.03	82.79	17.21

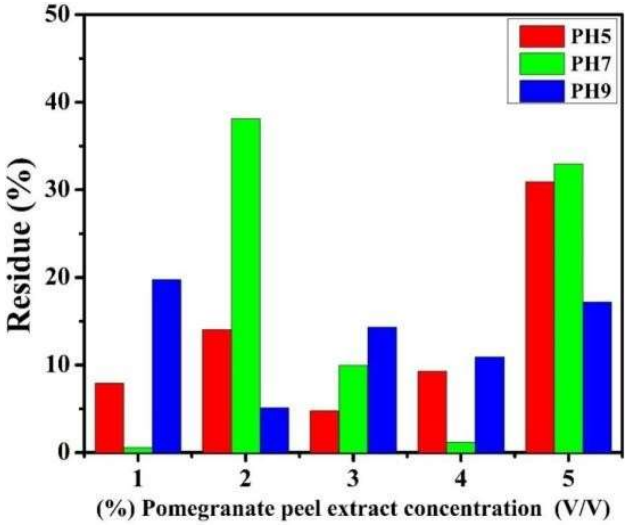


Fig. 6. Comparative thermo gram residue of various pomegranate peel extract concentration (1, 2, 3, 4 and 5%) at various PH5, PH7 and PH9.

The topmost decomposition maintained 94.89% in 2% pomegranate peel extract adsorbed cotton, which is thermally unstable than the others material. The maximum residue observed 19.79% in 1% of pomegranate peel extract adsorbed cotton which thermally more stable than the other pomegranate peel extracts adsorbed cotton.

The complete thermo gram remnants of various pomegranate peel extract concentration at various PH are manifested in Fig. 6. This graph discloses clearly that 1% of pomegranate peelextract exhibits lowest residue than the other material. Furthermore, the maximum residue observed from 2% of pomegranate peel extract concentration which thermally more stable thanthe other material.

4. Liquid MMT results of selected pomegranate peel dyed cotton fabric

Liquid moisture management properties of the selected pomegranate peel dyed cotton fabric results are presented in the table 6.

Table 6 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	OM MC
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom		
Mean	3.83	3.53	10.20	46.98	21	24	4.31	4.638	390.9693	0.81
S.D	1.83	1.79	4.22	9.62	4.18	2.23	1.01	0.923	50.0469	0.05
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

The table 6 conveys two values, namely; the grade values for the pomegranate peel dyed selected fabric and their moisture governance behaviors as well. The specified indices described these values, (Yao et al., 2006). It is the common phenomena and the chief concernthat any wound dressing material should acquire liquid moisture management properties. The results verified that the pomegranate peel dyed selected fabric consists the moisture management properties with various category of the indices. According to the specified classification,(Yao et al., 2006) the obligatory properties are medium to fast wetting, Mediumto fast absorption, large spread area at bottom surface, fast spreading at bottom surface and strong to excellent one –way transport.

Wetting time (medium to fast wetting)

Index values, for the pomegranate peel dyed fabric, are more than the indispensable level. The pomegranate peel dyed selected fabrics demonstrated very fast wetting time at the top and bottom surfaces.

Absorption rate of top surface (Medium to fast absorption)

The recommended grade for the absorption percentage is medium to fast absorption. The pomegranate peel dyed fabric illustrates 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 extraordinarily 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 sanction very fast grade indices and it was more thanthe predicted standard.

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

The test shows that the pomegranate peel dyed fabric depicts one-way transport index is very strong. The pomegranate peel dyed fabric showed 200-400 AOTI with very strong grade. Therefore, it was noted from the above shown table 8, it was concluded that the pomegranate peel dyed fabric obtained very srong to excellent grade and indices for the entire index achieved.

5. Ultra protection factor of the finished Fabric

From the above-mentioned figure 7, 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 encapsulates the impoverished protection against UV rays (UPF 12rating). Here it can be wound up that the detrimental effects of UV rays and their protection against them conserved textile material by using Pomegranate peel in the cotton fabric (figure9) accordingly**.**

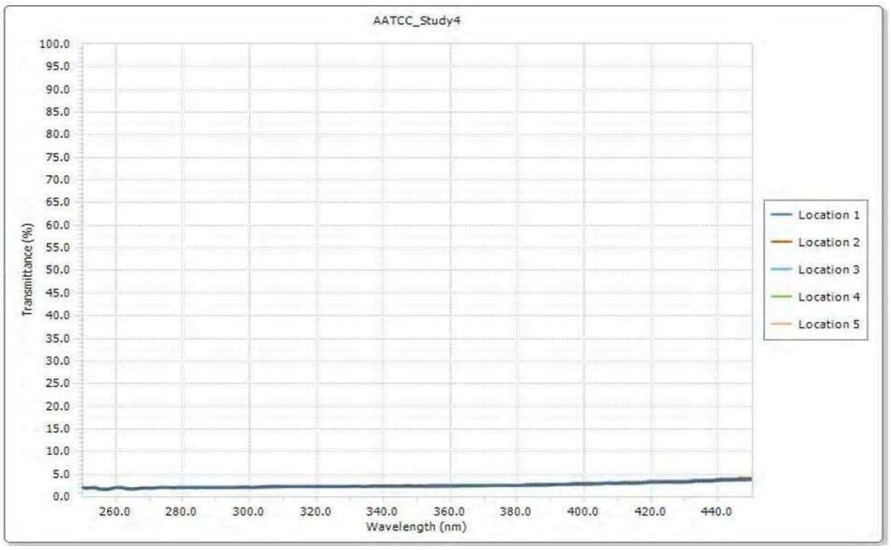


Figure: 7 UPF rating for treated sample

Conclusion

In this study, we thoroughly investigated the antimicrobial properties of cotton fabric dyed with pomegranate peel extract. Our research focused on evaluating the fabric's effectiveness against both Gram-positive (*Staphylococcus aureus*) and Gram-negative (*E. coli*)bacteria, as well as its antifungal activity against Aspergillus Flavus. Our findings revealed that fabric dyed at pH 7 with a 5% dye concentration exhibited the highest levels of antimicrobial and antifungal activities. This superior performance can be attributed to the greater availabilityof dye molecules in this specific configuration. Additionally, we conducted a comprehensive analysis of the color strength (K/S) of the pomegranate peel-dyed fabric, providing CIE lab coordinates to describe its color characteristics. The results indicated distinct color changes, with variations in lightness (L*), redness-greenness (a*), and yellowness-blueness (b*). Notably, the fabric dyed at 5% concentration exhibited higher redness values (a*) compared to the 1% concentration, demonstrating its richer color.The complete thermo gram remnants of several pomegranate peel extract concentration at various PH are revealed. This graph describesopenly and clearly that 1% of pomegranate peel extract exhibits stubby residue than the other material. Moreover, the highest amount of residue observed from 2% of pomegranate peel extract concentration which thermally steadier than the other material.

Furthermore, we examined the fabric's liquid moisture management properties, which are crucial for applications like wound dressing materials. Our tests revealed that the pomegranatepeel-dyed fabric exhibited excellent wetting, absorption, and spreading characteristics, meeting the requirements for effective moisture management. In addition to its antimicrobial and moisture management properties, we explored the fabric's ability to protect against UV rays. The results were remarkable, showing a significant increase in the Ultra Protection Factor (UPF) from 12 to 45 after treatment with pomegranate peel extract. This substantial enhancement underscores the

fabric's potential to provide effective UV protection, making it avaluable choice for sun-blocking application.

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