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Evaluation of Dyeing Properties of *Lawsonia Inermis* on Multi-Fibers through the Exhaust Method

[1]A. Hassan*, [1]S. Anjum, [1]Y. Kanwal, [2] M. Iqbal, [2]K. Ahmed, [1]I. Sabir, & [1]S. Pervaiz
[1]Department of Chemistry, Federal Urdu University of Arts, Science & Technology, Gulshan-e-Iqbal Campus, Karachi.
[2]PCSIR Laboratories Complex, University Road, Karachi-75280, Pakistan
*Corresponding Author email: atya007chem@gmail.com

Abstract:
Natural dyes are biodegradable, hypoallergenic, and nontoxic, reducing the amount of pollutants released into the environment, while synthetic dyes are responsible for generating environmental pollution in water, soil, and air. These synthetic dyes produce skin irritation and toxicity. This study used *Lawsonia Inermis*, commonly called heena leaves,to extract a natural colourant used as a coloring agent for ladies' hands and feet during festivals and ceremonies. Currently, Metallic mordants such as copper sulphate ($CuSO_4$), ferrous sulphate ($FeSO_4$), and ferric chloride ($FeCl_3$) are used to change the hue of natural dyes and applied on multi-fiber fabric by the exhaust method. Multi-fiber fabric is a special type made from a blend of unlike fibers such as cotton, cellulose acetate, polyacrylonitrile, polyamide, polyester, and wool. This fiber can be used in various applications as per the industry's requirements. Lawson dye was extracted from henna leaves in aqueous medium at room temperature, 30±1°C. However, the color fastness, color strength (K/S), washing fastness, % Reflectance,and colour space (CIEL*a*b*) were observed in acidic and basic media. In colour space of the sample, L^* is used to measure light fastness, and a^*,b^* are used to measure green-red, blue-red color components, respectively. Colour strength (K/S) was determined through a colorimeter. The CIE L^*, a^*,b^* properties identified in two different lights, such as D65/10°, TL84-10. During this work, it was observed that after washing, the value of L^* and b^* increases, and the value of a^* decreases, indicating that samples become lighter and yellower. This result revealed that the color strength and fastness properties are higher in alkaline than in acidic medium. Cellulose acetate, cotton, and polyamide show good resistance to light.

Keywords: *Lawson Iainermis,* multi fiber fabric, aqueous medium, color fastness, strength (K/S), (CIEL*a*b*)

1. INTRODUCTION

Dyeing is a process in which colour is fixed from the liquid phase to the solid phase. Various dyeing methods, such as batch dyeing, continuous dyeing, and semi-continuous dyeing, are used for dyeing textile fabrics. The batch dyeing is commonly known as exhaust dyeing. In this method, all auxiliaries for dyeing, including fabrics, are put into the dye bath and kept in the dyeing machine. Most textile industries adopt the continuous dyeing process; substrates are continuously provided into the dye range [1]. Dyes are characterized by their colour fastness, K/S values, and leveling properties. Colour fastness properties are essential parameters that explore the fixation of dye to the fabric. Mordant is an intermediate chemical substance that can fix color on fiber. Metallic compounds are used as mordants such as copper sulphate ($CuSO_4$), Ferric Chloride ($FeCl_3$), Zinc hydroxide [$Zn(OH)_2$], etc. These metallic substances can make a coordination complex with dye and enhance the fixation power of dye [2]. In the textile sector, demand for natural dyed fabric is increasing day by day. Because natural dyes are eco-friendly and skin-friendly [3]. Natural colorant is decomposed easily compared to synthetic colour. The consumption of synthetic dyes enhances water pollution over time, and their release after prime use is toxic to the marine ecosystem and seawater life [4, 5]. Heena leaves extract has medicinal importance due to its many biological activities such as Antifungal [6], Antibacterial [7], Antiviral, Immunomodulatory, Wound healing, and Anticoagulant. Nootropic, Hepatoprotective, Enzyme inhibitory, Tuberculositatic, Antidiabetic, Anti-inflammatory, analgesic, and antioxidant activities. These biological properties of heena leaves extract make them unique compared to synthetic colour [8]. *Lawsonia inermi*s belongs to the *Lythraceae* family. The size of the plant may be smaller or longer, so it's placed in the shrub category. Generally, the height of the plant is 2.6 m. *Lawsonia inermis* leaves may be white or red with a specific fragrance. When the henna plant is grown between 35 and 45°C, it produces the most soluble dyes. [9] Lawsone is the active component of Henna leaf extracts. The IUPAC name of lawsone is 2-hydroxy-1,4-naphthaquinone structure [10 -11](Fig. 1).

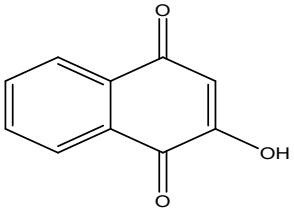

Figure 1: *Lawsoniainermis*

Various research works have been reported regarding henna leaves extract used as a natural colorant in the dyeing of silk and cotton [12-13]. The effect of pH has also been reported in the dyeing of silk and protein fiber [4]. The ethanolic extract with different mordants in cotton fiber dyeing and its colour fastness was also reported [14]. Henna extracted dye

is not only used for nail paint and hair dye but can also be used as a natural dye in the textile industry for dyeing different textile fibres such as cotton, silk, polyester, and others [15]. Different mordant and dyeing conditions were applied for dyeing silk fibre in acidic (pH=5) and basic (pH=9) media. Henna leaves extract used as a natural dye and potash alum used as a mordant are not harmful to the skin and environment [16]. Numerous organic solvents and water are used to extract Henna leaves' dyes. The extracted dye was applied on silk and cotton and evaluated for properties such as colour fastness, K/S values, rubbing, refractive index, etc. [5]. *Lasonia Inermis* extract (henna dye) has shown reasonable dye capability towards cotton fabrics as compare with reactive dye [17]. Different colour grading was reported with the mixing of varying ratios of metallic mordant ($CuSO_4$) with henna leaves extract. Further, dyes and mordants were applied to cotton fibre [18]. Some work has also reported that henna leaves extract is used without mordant in polyester fiber [19]. Various natural dyes were also used to test the colour fastness properties of cotton fiber [20]. The qualitative and quantitative properties of extracted henna leaves are reported [3]. Different % ratios of extracted henna leaves were applied to cotton and polyester fiber at different temperatures [10]. The colour quality and tensile effect after natural dyeing on silk fiber [21]. Henna leaf dying extract showed an excellent shielding effect against the harmful UV radiation without changing their performance and properties [22]. Cotton fiber was dyed with henna leaves liquor under two conditions: irradiated and non-irradiated by UV light. They observed that light fastness and colour quality were enhanced due to pre-irradiation of cotton fiber against the UV light [23]. This work determines the abrasion strength and porosity for with and without coated dyed cotton fabrics [24]. Different irradiation doses of gamma rays were applied to the cotton fabrics, and the dyeing properties of radiated and irradiated henna leaves dye [25] were evaluated. A good dyeing result was observed with cotton fiber in an alkaline medium compared to aqueous by the exhaust method, followed by comparison with colour properties with synthetic dye.

The novelty of this study lies in prescribing the condition of natural dyeing using henna leaves extract in multi-fiber substrate, which has not been reported before. However, study the effect of mordant in basic and acidic media during the dyeing of multi-fiber fabric. Colour quality, including color strength (K/S), washing fastness, % reflectance, washing fastness using data colour, staining due to perspiration, staining due to washing, and light fastness properties have been evaluated.

2. MATERIALS AND METHODS

2.1. Material Collection

Heena leaves were collected from the Garden of the Department of Chemistry, Federal Urdu University of Arts, Science & Technology, Gulshan-e-Iqbal Campus, Karachi.

2.2 Sample preparation for the extraction of dye

Collected plant materials were washed with distilled water three times to remove all dust particles, then dried and ground in a grinder for the dye extraction (Fig. 2).

Figure 2: Dye sample extraction preparation.

2.3. Extraction of *LawsoniaInermis* Dye

100gm of leaf powder was poured into one liter (1L) of water and kept for 24 hours at room temperature. The solution was heated slowly until it became reddish brown followed by filtration using a filter paper. Filtrate was ready for dyeing.

2.4. Dyeing

The aqueous solution of dye was used for dyeing purposes. Acidic and basic media were selected for exhaust dyeing and applied to the substrate. Sodium carbonate (Na_2CO_3) solution was used to maintain the pH within 9.2-10.4 of the dyeing bath at room temperature. 5 gm of mordant $CuSO_4$ was added during the dyeing process. The same procedure was followed with each mordant.

2.5. Washing standard method

The washing standard method is a guideline for washing and cleaning textile fabrics and other materials in this regard, soap and detergent were used to evaluate the colour fastness to washing. Fabric samples were cut 10 cm×4 cm and sewn with the same size of untreated multi-fiber. There was ISO-105-CO6 to check the color fastness from washing. According to ISO recommendation CO6, the sample is treated in a washing apparatus at 60 ± 2°C for 30 minutes using color fastness sodium perborate 2g/L, and 10 steel discs to a given liquor ratio of 1:50, finally washed with cold water and dried. The same procedure was done with a sample in the presence of mordant in acidic and alkaline conditions.

2.6. Colour fastness to perspiration:

Colourfastness to moisture assesses the ability of the fabric to resist colour change or draining of colours with human sweating. Samples of the dyed multi-fiber joined with undyed multi-fiber are treated in two different solutions containing

L-histidine, drained, and placed between two plates under a specified pressure in a perspiration meter. ISO-105-E04 is used to measure color fastness to perspiration.

2.7. Colour Fastness to light:

The standard method for testing colour fastness to light in textile materials involves exposing the fabrics to artificial light sources that mimic natural daylight. The multi-fiber dyed samples were cut 10 cm×4 cm and kept in a light fastness tester for 100 hours. After 100 hours, test samples are compared with the Blue scale or Computer Color Matching System (CCMS) [6].

3. RESULTS AND DISCUSSION

Heena leaves extract is used to dye multi-fiber fabrics through the acidic and alkaline media exhaust dyeing method. Metallic salts were used as mordants in dyeing phenomena. Multi-fiber fabric is a kind of fabric that is manufactured with different classes of yarn. Each fabric is joined together like a strip at least 15 mm wide. It comprises strips of Cellulose acetate. Cotton, polyamide, polyester, polyacrylic, and wool. The wonderful colour patterns obtained by dissimilar or single dyes on a single yarn of multi-fiber fabric. This multi-fiber helps to communicate with students regarding the structures of dye and fabric molecules, and the interaction between them is either chemisorption or physisorption. The undyed multi-fiber (Fig. 3) consists of different yarns.

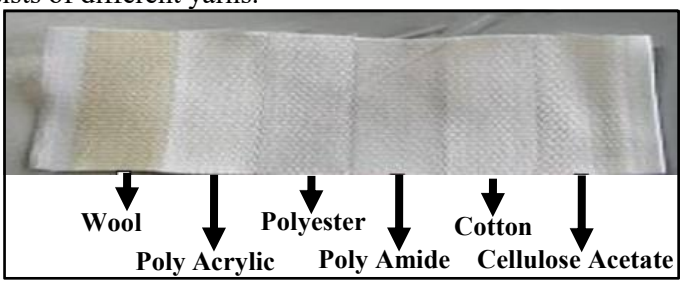

Figure 3: Undyed Multi-Fiber fabric

3.1. Chemistry of Dyeing with Fabrics

Multi-fibre is used as an indicator fibre to confirm dyeing and is shown in (Fig. 4). Reported work reveals that lawsone is a colouring agent found in heena leaves extract. The affinity of dyes towards fibres due to the ion-dipole interaction between the *lawsone's* polar groups and protonated amino groups, resulting in the dye being fixed onto the protein fibre. Cellulose fibres comprise limitless polar hydroxyl (-OH) groups. These hydroxyl groups (-OH) enhance the swelling property, reactivity, and moisture absorption. These properties are responsible for diffusing the dye into fibre pores [19]. Furthermore, phenolic-OH-OH escalates the dye exhaustion of silk fabric. This may be due to Lawson's low substantively towards cellulose fibre, cotton, and linen, which are significantly lower in the degree of dye exhaustion when compared to protein fibre [13]. Polyester fiber is hydrophobic and has low polarity and less absorbing capacity, so less dye fixation occurs on it because the dyeing result is not good compared to other fibers [19].

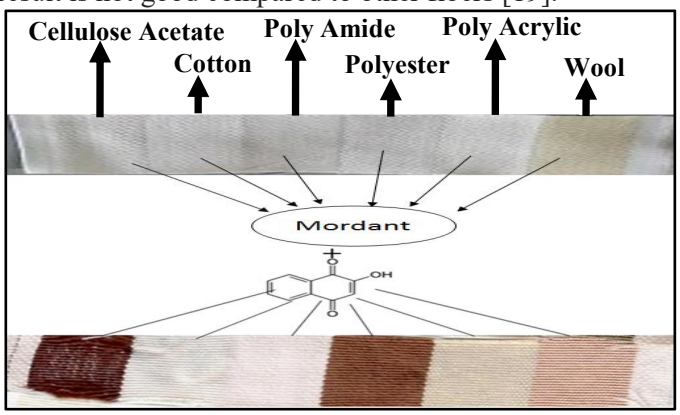

Figure 4: Interaction dyes and mordant with of Multi fiber fabric.

3.2 Washing Fastness:

The presence of OH and C=O in the lawsone structure led to the formation of ternary copper (II) complexes in the fabrics, resulting in the natural dye's higher color strength and good washing properties. In alkaline medium *lawsonia inermis* showed better washing properties than acidic medium because the complex formation is pH dependent, and the ternary copper (II) complex is more stable in alkaline medium. The various salts used as mordants, such as Ferrous Sulphate ($FeSO_4$), Ferric Chloride ($FeCl_3$), and copper sulphate ($CuSO_4$), were found to be the most effective for improving the colour strength (K / S) of wool fibre. In basic mediums, better results of washing fastness were found in cellulose acetate, polyester, and polyacrylic, while cotton and polyamide reflect better outcomes in acidic mediums (Fig.5) and Table 1. In the textile field, the grey scale can accurately assess color fastness and ensure that the products meet the required standard.

Table 1: Washing Fastness By Using Gray Scale

Fiber	Washing Fastness/Change In Shade In Alkaline Medium	Washing Fastness In Acidic Medium
Cellulose acetate	2.0	2/3
Cotton	3/4	3.0
Poly amide	2/3	2.0
Poly ester	4.0	1.0
P-oly acrylic	4.0	1.0
wool	1/2	1.0

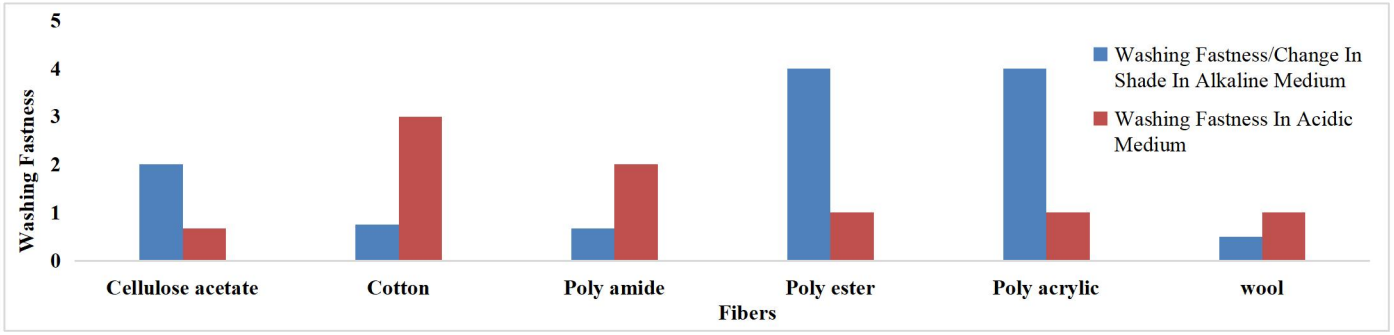

Figure 5: Washing fastness using grey Scale

3.3 Percent (%) Reflectance:

Percent (%) reflectance is commonly estimated via a spectrophotometer or colorimeter. This property tells us the ratio of reflected light to the incident light. This parameter evaluates two yellow objects and different textures. It provides information about the analyte structure through absorption or transmittance of light. Reflectance measures a sample's colour, or examines differences between objects for sorting or quality control. Polyester shows high % reflectance in both acidic and alkaline media, presented in Fig. 6 and Table 2.

Table 2: Refractive Index of Multi-Fiber in Acidic Mediu

Fiber	% Reflectance In Alkaline Medium	% Reflectance In Acidic Medium
Cellulose acetate	57	44
Cotton	60	60
Poly amide	37	46
Poly ester	71	66
Poly acrylic	65	57
Wool	24	24

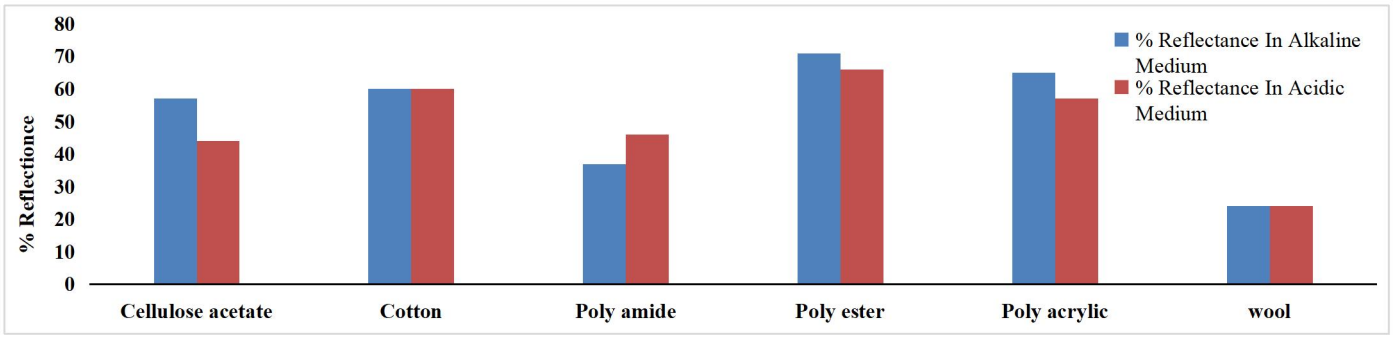

Figure 6: % Reflectance of fiber in Acidic and Basic medium.

3.4 Washing fastness by using the data colour

In dyeing, washing fastness is considered an important parameter. It is used to measure by data color in two different light D 65 10 ºC and TL 84-10. The positive value of ΔL* for cellulose acetate shows that the colour becomes lighter after washing due to the low substantiveity of lawsone towards cellulose fiber, which is significantly lower in the degree of dye exhaustion compared to protein fiber[13]. Positive value of Δa* shows that after washing, it becomes redder. The negative value of ΔL* of polyamide, poly acrylic, and wool shows less fading during washing because the protonated amino group attracts lawsone anions towards the protein fiber. The affinity is mainly due to the ion-dipole interaction between the lawsone's polar groups and protonated amino groups, contributing to henna dye fixation onto protein fibre [19]. Washing fastness was presented in Tables 3 and 4.

Table 3: Colour variations of washing treatment on dyed multi-fiber in alkaline medium

Fiber	Light	L*	a*	b*	c	h	x	y
Cellulose Acetate								
Un washed	$D_{65}/10^0$	48.60	1.93	18.31	18.41	83.99	0.3731	0.3855
	msTL84-10	49.39	1.88	20.47	20.55	84.75	0.4380	0.4134
washed	$D_{65}/10^0$	69.53	9.66	20.24	22.43	64.47	0.3776	0.3685
	msTL84-10	70.92	9.17	23.07	24.82	68.31	0.4442	0.3977
Cotton								
Un washed	$D_{65}/10^0$	63.06	1.49	15.85	15.92	84.64	0.3556	0.3702
	msTL84-10	63.79	1.91	17.83	17.93	83.90	0.4244	0.4018
washed	$D_{65}/10^0$	72.57	1.04	17.41	17.44	86.60	0.3537	0.3701
	msTL84-10	73.31	1.92	19.58	19.68	84.40	0.4233	0.4015
Polyamide								
Unwashed	$D_{65}/10^0$	52.34	8.65	13.67	16.18	57.68	0.3726	0.3603
	msTL84-10	53.34	8.10	15.65	17.62	62.64	0.4403	0.3912
washed	$D_{65}/10^0$	41.78	11.02	19.77	22.63	60.85	0.4101	0.3799
	msTL84-10	43.05	10.38	22.45	24.74	65.18	0.4717	0.4029
Polyester								
unwashed	$D_{65}/10^0$	72.71	1.37	13.36	13.43	84.14	0.3455	0.3605
	msTL84-10	73.40	1.66	14.97	15.06	83.66	0.4151	0.3945
washed	$D_{65}/10^0$	83.42	1.74	9.09	9.26	79.16	0.3343	0.3483
	msTL84-10	83.93	1.93	10.33	10.51	79.39	0.4053	0.3850
Polyacrylic								
unwashed	$D_{65}/10^0$	75.09	2.72	7.23	7.73	69.38	0.3338	0.3449
	msTL84-10	75.57	2.74	8.27	8.71	71.66	0.4050	0.3819
washed	$D_{65}/10^0$	73.30	0.94	14.02	14.05	86.17	0.3459	0.3622
	msTL84-10	73.99	1.32	15.70	15.76	85.19	0.4155	0.3959
Wool								
unwashed	$D_{65}/10^0$	53.47	11.69	19.82	23.01	59.47	0.3958	0.3721
	msTL84-10	54.84	10.93	22.56	25.07	64.16	0.4599	0.3985
washed	$D_{65}/10^0$	42.62	3.35	13.96	14.36	76.51	0.369	0.3741
	msTL84-10	43.37	3.12	15.76	16.07	78.81	0.4353	0.4041

Table 4: Colour Variation of washing Treatment on dyed Multi Fiber in Acidic medium

Fiber	Light	L*	a*	b*	c	h	x	y
Cellulose acetate								
Un-washed	$D_{65}/10^0$	77.02	4.00	10.21	10.97	68.60	0.3418	0.3499
	msTL84-10	77.72	3.89	11.66	12.30	71.54	0.4123	0.3857
washed	$D_{65}/10^0$	58.52	5.51	18.86	19.64	73.72	0.3745	0.3753
	msTL84-10	59.58	5.56	21.41	22.12	75.45	0.4414	0.4039
Cotton								
Un-washed	$D_{65}/10^0$	80.85	2.58	7.63	8.05	71.33	0.3332	0.3450
	msTL84-10	81.34	2.65	8.70	9.09	73.07	0.4044	0.3820
washed	$D_{65}/10^0$	52.84	5.52	13.35	14.45	67.53	0.3641	0.3633
	msTL84-10	53.66	5.47	15.20	16.16	70.22	0.4328	0.3947
Polyamide								
Un-washed	$D_{65}/10^0$	50.71	10.92	17.34	20.49	57.81	0.3982	0.3680
	msTL84-10	51.94	10.08	19.76	22.18	62.96	0.4660	0.3960
washed	$D_{65}/10^0$	39.58	8.66	18.11	20.07	64.45	0.4014	0.3806
	msTL84-10	40.71	8.24	20.53	22.12	68.12	0.4644	0.4047
Polyester								
Un-washed	$D_{65}/10^0$	76.38	3.13	8.20	8.78	69.14	0.3363	0.3465
	msTL84-10	76.91	3.15	9.37	9.88	71.41	0.4073	0.3830
washed	$D_{65}/10^0$	60.79	4.34	11.84	12.61	69.85	0.3526	0.3576
	msTL84-10	61.52	4.38	13.49	14.18	72.00	0.4224	0.3911
Polyacrylic								
Un-washed	$D_{65}/10^0$	75.09	2.72	7.23	7.73	69.38	0.3338	0.3449
	msTL84-10	75.57	2.74	8.27	8.71	71.66	0.4050	0.3819
washed	$D_{65}/10^0$	59.87	4.50	13.11	13.87	71.05	0.3567	0.3611
	msTL84-10	60.66	4.52	14.92	15.60	73.14	0.4260	0.3937
Wool								
Un-washed	$D_{65}/10^0$	53.47	11.69	19.82	23.01	59.47	0.3958	0.3721
	msTL84-10	54.84	10.93	22.56	25.07	64.16	0.4599	0.3985
washed	$D_{65}/10^0$	37.65	9.58	14.71	17.55	56.93	0.3953	0.3691
	msTL84-10	38.67	8.96	16.75	19.00	61.86	0.4598	0.3958

3.5. Determination of Color strength (K/S):

The colour strength of a dye is a measure of its ability to impart colour to other materials. It is the ratio of absorbance (K) and scattering colour strength (S), and represented as (K/S). It is the most critical parameter for testing the quality measurement of a sample in terms of the depth of the colour dyed fabric. K/S value is found to be higher for polyamide fiber than for cellulose and cotton fibers. This is due to the attraction of the proton of an amino group toward the anion of *lawsone*. In basic and acidic media, the K/S values were found to be decreased with increasing wavelength, as shown in Figures (7) and (8) and Tables (5) and (6). ΔE * (DeltaE) estimates the colour difference between two colours in colour chemistry. Various formulas are used to calculate the E *, such as CIE76 and CIE94. These parameters help to identify the colour consistency and achieve the target colour disclosed in the Table. (7).

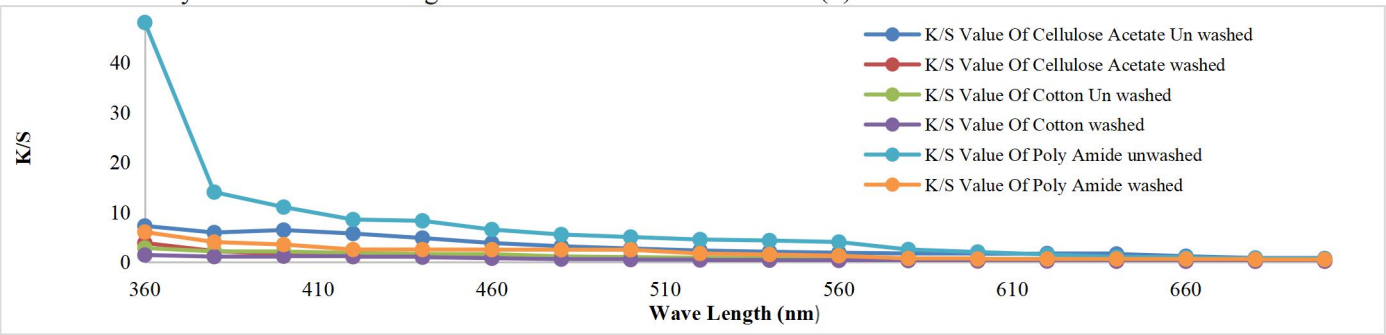

Figure 7: K/S values of unwashed and washed in basic medium

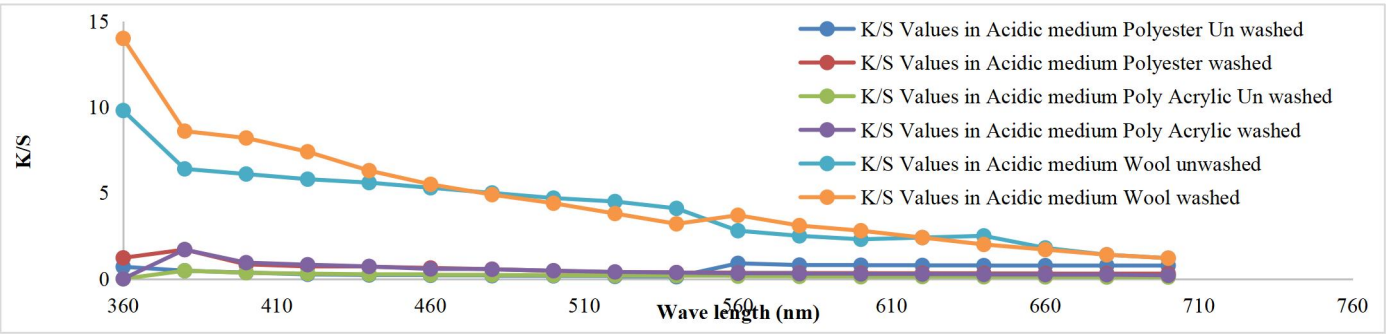

Figure 8: K/S values of unwashed and washed in Acidic medium

Table 5: Colour Strength (K/S) In Basic Medium at different wavelengths

Wave Length	K/S Values in Basic Medium					
	Cellulose Acetate		Cotton		Poly Amide	
	Un washed	Washed	Un washed	washed	unwashed	washed
360	7.22	3.8	2.8	1.4	48	6.0
380	5.9	2.2	2.12	1.08	14	4
400	6.4	1.5	2.08	1.17	11	3.5
420	5.7	1.3	1.84	1.06	8.5	2.5
440	4.8	1.2	1.58	0.96	8.25	2.49
460	3.8	1.1	1.56	0.75	6.5	2.47
480	3.15	0.9	1.12	0.57	5.5	2.46
500	2.7	0.8	0.98	0.48	5.0	2.45
520	2.3	0.7	0.84	0.4	4.5	1.7
540	2.05	0.6	0.74	0.36	4.3	1.5
560	1.85	0.35	0.70	0.32	4.0	1.25
580	1.7	0.3	0.66	0.3	2.5	0.7
600	1.65	0.2	0.56	0.26	2.0	0.6
620	1.7	0.2	0.54	0.22	1.5	0.6
640	1.6	0.15	0.53	0.22	1.0	0.6
660	1.15	0.15	0.46	0.20	0.9	0.58
680	0.8	0.15	0.38	0.20	0.7	0.5
700	0.7	0.15	0.30	0.20	0.6	0.5

Table 6: Colour Strength (K/S) in Acidic Medium at different wavelengths.

Wave Length	K/S Values in Acidic Medium					
	Polyester		Poly Acrylic		Wool	
	Un washed	Washed	Un washed	washed	unwashed	washed
360	0.7	1.22	-	-	9.8	14
380	0.47	1.7	0.47	1.7	6.4	8.6
400	0.36	0.84	0.35	0.94	6.1	8.2

420	0.26	0.72	0.30	0.82	5.8	7.4
440	0.22	0.70	0.26	0.72	5.6	6.3
460	0.20	0.63	0.23	0.57	5.3	5.5
480	0.18	0.56	0.22	0.55	5.0	4.9
500	0.17	0.46	0.2	0.47	4.7	4.4
520	0.14	0.38	0.185	0.40	4.5	3.8
540	0.12	0.36	0.180	0.36	4.1	3.2
560	0.90	0.34	0.15	0.32	2.8	3.7
580	0.80	0.33	0.14	0.30	2.5	3.1
600	0.79	0.32	0.12	0.28	2.3	2.8
620	0.78	0.32	0.128	0.27	2.4	2.4
640	0.77	0.31	0.117	0.25	2.5	2.0
660	0.77	0.30	0.110	0.24	1.8	1.7
680	0.77	0.30	0.1	0.238	1.4	1.4
700	0.77	0.30	0.1	0.2	1.2	1.2

Table 7: Colour Strength K/S and ΔE* Values of Different Fiber

Fiber	ΔE*(Acidic)	ΔE*(Basic)	K/S(acidic)	K/S(basic)
Cellulose acetate				
$D_{65}/10^0$	20.48	28.44	9.4	7.2(u.w)
msTL84-10	20.66	28.56	3.0	3.6
Cotton				
$D_{65}/10^0$	28.75	19.04	4.57	2.8
msTL84-10	28.57	19.22	1.1	1.4
Polyamide				
$D_{65}/10^0$	11.38	4.98	22	6.0
msTL84-10	11.41	5.06	5.0	40.0
Polyester				
$D_{65}/10^0$	16.06	6.00	3.0	1.52
msTL84-10	15.99	6.20	0.83	1.02
Polyacrylic				
$D_{65}/10^0$	16.42	7.24	3.57	1.22
msTL84-10	16.42	7.73	0.8	0.70
Wool				
$D_{65}/10^0$	16.77	14.89	13.0	14.0
msTL84-10	17.29	15.45	6.0	9.6

3.6. Determination of Staining due to perspiration:

Staining due to perspiration refers to the discoloration or marks that occur when sweat comes into contact with fabric. Human sweat contains water, salts, proteins, and other substances that can react with dyes or fibers. Factors contributing to staining include pH imbalance, sweat composition, and moisture retention. Human sweat can be acidic or alkaline, affecting dye stability on fabrics and leading to colour fading of the dye. Notably, staining due to perspiration in alkaline medium was lower in wool and cotton than in cellulose acetate, polyamide, and polyacrylic. Whereas staining in acidic medium was found to be higher across all fabric types, as illustrated in Figure (9) and Table (8).

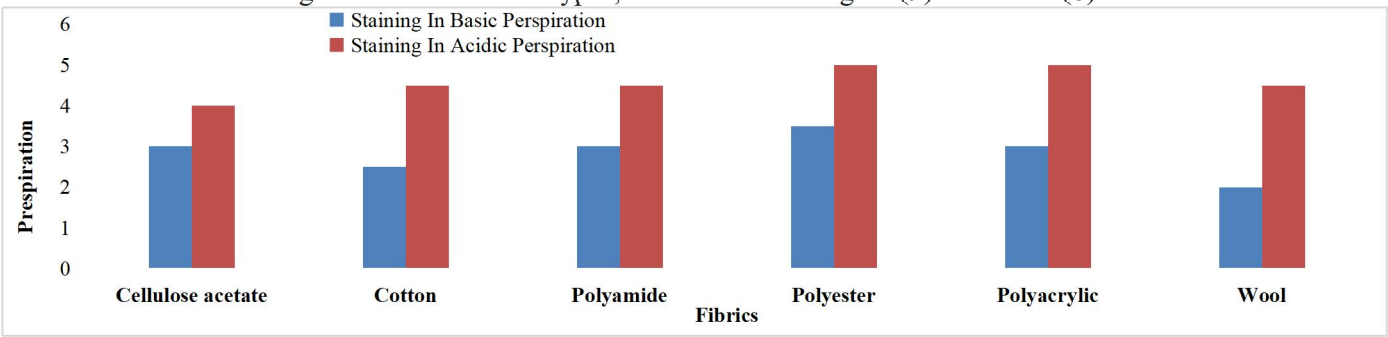

Figure 9: Staining due to perspiration in Acidic medium and Basic medium

Table 8: Staining due to perspiration in Basic and Acidic media

Fiber	Staining in Basic Perspiration	Staining in Acidic Perspiration
Cellulose acetate	3.0	4.0
Cotton	2.5	4.5
Polyamide	3.0	4.5
Polyester	3.5	5.0
Polyacrylic	3.0	5.0
Wool	2.0	4.5

3.7. Determination of Staining due to washing:

Grey scale was used to measure the staining. Compare the contrast between the treated and untreated samples with the changing grey scale and staining of colour in the adjacent multi-fiber fabric with the staining grey scale. This assessment is done in a colour matching cabinet under standard lighting of D65 (artificial daylight). Cellulose acetate shows less staining value because of the strong attraction of absorbed dye with fiber, as shown in Table (9).

Table 9: Staining due to washing in Acidic & Basic medium

Fiber	Staining in an alkaline solution	Staining in acidic solution
Cellulose acetate	4.0	4/5
Cotton	3.0	4.0
Polyamide	40	4.0
Polyester	4.0	4/5
Polyacrylic	4.0	4/5
Wool	3/4	4/5

3.8. Determination of Light Fastness:

Blue scale is used to measure light fastness. Cotton shows good fastness properties in both media. Light fastness of polyester was very low as compared to cellulose acetate, cotton, polyamide, polyacrylic, and wool in alkaline media, while the effect of light fastness in polyamide was found to be lower as compare to other fabric strips in acidic medium. At the same time, the reverse result was observed in polyester, polyacrylic, and wool fiber as indicated in Table 10.

Table 10: Light Fastness Values In Both Media

Fiber	Light Fastness In Alkaline Solution	Light Fastness In Acidic Solution
Cellulose Acetate	5.0	4.0
Cotton	5.0	5.0
Polyamide	6.0	3.0
Polyester	1.0	4.0
Polyacrylic	4.0	6.0
Wool	4.0	6.0

CONCLUSION

It was concluded that cellulose acetate, cotton, and polyamide established good light resistance among the tested fibers, as evidenced by their color fastness and overall color performance. The exhaust dyeing technique was employed using natural dyes, with metallic mordants Ferric Chloride ($FeCl_3$), Ferrous Sulphate ($FeSO_4$), and Copper Sulphate ($CuSO_4$) to enhance dye uptake and color properties, and was found effective. To evaluate the dyed fabrics under both acidic and alkaline conditions, the following parameters were assessed: colour strength (K/S values), percentage reflectance, washing fastness (supported by data from Data colour analysis), staining due to perspiration, staining due to washing, and light fastness.

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