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ORIGINAL ARTICLE

Study the effect of metal ion on wool fabric dyeing with tea as natural dye

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Abstract Aqueous extract of natural dye, tea was dyed on the wool fabric with dark brown for 2% and 5% shade. The tea containing tannins as the main colorant species to produce different shade with different mordant salts. The mordant salts Alum, $CuSO_4$, $FeSO_4$, $ZnSO_4$, Na_2SO_4, and $MgSO_4$ were used to dye fabric using three different dyeing methods: pre-mordanting, meta-mordanting and post-mordanting. The color of the fabric was investigated on Data Color matching system in terms of K/S and CIE Lab-color difference values. The post-mordanting method gave the great depth of shade of natural dye tea with 2% and 5% shade, it also give good light fastness and wash fastness properties. Copper was found as a good mordant to achieve the best results with transition metal ions effect. Deep shades (K/S = 17.50) were obtained for original sample of 5% with color difference **DE** value is 0.17, as compare to 2% original sample of tea of light brown shades (K/S = 10.50) with color difference **DE** value is 0.50 under maintained temperature at 85 °C for 35 min of dyeing.

1. Introduction

Natural dyes contain natural coloring matter. Which are neither carcinogenic nor hazardous to environment, the colors are soothing to eyes, earthly, warm and highly appealing. The dyes being natural are earth friendly and help maintain and ecological balance (Mahatma and Tamari, 2005). They are non-allergic, non-toxic to human body and perpetuate an ancient tradition. In 1905 Adolf von Baeyer (the scientist who also formulated aspirin) was awarded the nobel prize for discovering the molecular structure of indigo, and developing a process to produce it synthetically (Ishii et al., 1995; Deo and Desai, 1999).

In spite of their inferior fastness, natural dyes are more acceptable to environmentally conscious people around the world (Chandramouli, 1995). The commercially successful natural dyes, tea is unique because of its widespread use as a beverage. Tea plant is classified as Camellia Sinensis – variety sinensis and variety assamica. There are six types of teas: green, yellow, dark, white, oolong and black. This classification is based on the processing method employed, the degree

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of fermentation and the oxidation of the polyphenols present in tea (Gulrajani, 1992). The different classes of compound found in tea include: amino acids, caffeine, carbohydrates, carotenoids, chlorophyll, lipids, mineral, nucleotides, organic acids, polyphones, saponins, unsaponifiable compound and volatile compounds of the polyphenols, catechins are the principle colorant species. Consider research work is being undertaken around the world on the application of the natural dyes (Gulrajani, 2001; Iriyama et al., 1974). Recently paper has published an exhaustive review on the subject of the natural dyes in textile application. However, there is work reported in the literature on the use of the tea as natural dyes in the textile application such as cotton and jute fabric (Tsatsaroni and Liakopoulou-Kyriakides, 1995).

Wool is the fibre from the fleece of the domesticated sheep. It is a natural, protein, multiple cellular, staple fibre density of wool is 1.31 g/cm^3, which tends to make wool a medium weight fabric. The wool fibre is a crimped, fine to thick, regular fibre. Fine wool may have as 10 as crimps per centimeter, whilst coarse wool have less than four crimps per 10 cm (Krishnamurthy, 1999). As the diameter increase, the number of crimps per unite length decreases. The number of crimps per unite length may be taker as an indication of wool fibre diameter wool fibre fastness. Wool fibre may be varying from off-white to light cream in color. This variation in color is due to the disulphide bond, which seems to be able to act as chromophores. As a result of incident light may be modified to cause the reflected light to have a ting yellow, giving the wool fibres their off-white appearance. When the fibre is cream to dark cream in color, this is due to more to polymer degradation on the surface of the fibre. This can readily occurs, as the wool polymer is chemically very sensitives to atmospheric oxygen and air pollutants. Using natural plant dyes to dye wool brown, yellow, orange, or green with different natural dyes made from plants (Hill, 1997).

The term mordant is derived from the Latin *mordere*, to bite. Mordant are substances which are used to fix a dye to the fibres. They also improve the take-up quality of the fabric and help improve color and light-fastness. These are considered as mordant dyes as they require the inclusion of one or more metallic salts of aluminums, iron, zinc, copper and others for ensuring reasonable fastness of the color to sunlight and washing. These metallic salts combine with the dyestuff to produce dye aggregates, which cannot be removed from the cloth easily.

Some transition metal ions can bond strongly with tea dye molecule, production deep color on the fabric. Other non-transition element can also produces color, but with less intensity. The metal mordant used in this study can split into three groups as follows. Group-1: (Na, Mg are belong to 1A and 11A), Group-11 (Alum is belong to 111A) and Group-111 (Cu, Zn are belong to 1B, 11B and Fe is belong to V111B). These metals are used in salts form of Alum, $CuSO_4$, $FeSO_4$, $ZnSO_4$, Na_2SO_4, and $MgSO_4$.

2. Experimental

2.1. Material

A commercial sample of black tea (Lipton Tazz Leaf tea powder, marked by Pakistan Unilever Brother Ltd., Pakistan was used. Commercially bleached wool fabric cut into rectangle pieces of 10×12 cm, weighting 2.0–2.5 g, respectively, were used for dyeing. Aqueous solution containing 5 and 10 g L^{-1} of ferrous sulphate, aluminum potassium sulphate, cupper sulphate, zinc sulphate and magnesium sulphate were used as mordant.

2.2. Extraction and preparation

Adding 2 and 5 g commercially available tea powders to 100 ml distilled water prepared aqueous extract of tea. The mixture was stirred, heated and hold at the boil for 30 min, allowed to standing for 15 min and then filtered. The filtrate was used for dyeing. To make the dye fix to the wool, it is usually necessary to boil the wool first with a ''Mordant''. This is a chemical, which attaches itself to the fibre; the dye then sticks to the chemical. The dye can either be extracted into solution and the wool then added, or the pre-mordant wool can be put in a pan with the dyestuff and water, and boiled up together. After dyeing, the wool needs thorough rinsing, and then hot washing in soap or detergent solution to remove any dye, which has not attached to the fibre.

2.3. Dyeing without a mordant (original sample)

The fabric were dyed at a liquor ratio of 30:1, in the dye bath. The temperature was raised to 85 °C for 30 min. The dyeing was carried out in cups of dyeing bath machine. The dyed fabric was then rinsed with water followed by soaping with 2 g L^{-1} washing powder, a nonionic soap at 60 °C. Finally the fabric sample were washed thoroughly with cold water, squeezed and dried at 60 °C. The original sample were dyed for 2% and 5% shade depth of tea dye and the result obtained showed similar trends to those reported below for the paler dyeing.

2.4. Dyeing with mordant

The following three dyeing methods were employed to dye wool fabrics using mordant:

(a) Pre-mordanting.
(b) Meta-mordanting.
(c) Post-mordanting

In mordanting method, 5 and 10 g mordant for per liter was used.

In pre-mordanting method, the fabric were first immersed in an aqueous solution of ferrous sulphate, aluminum potassium sulphate, copper sulphate, zinc sulphate and magnesium sulphate were dyed for 45 min at 30 °C. All the mordant fabric was dyed by the above method.

In the meta mordant dyeing method (i.e. dyeing in the presence of mordant), the fabric were immersed in a dyeing bath containing a mordant and the dye extract, and the dyeing bath was maintain the temperature at 85 °C for 35 min. The fabric were rinsed, soaped with nonionic soap at 60 °C, washed with water, squeezed and dried.

In the post mordant method, dyeing was carried out in the absence of a mordant, followed by mordanting in a separate bath containing a mordant at 30 °C for 45 min, further processing was the same as described in the meta-mordanting method.

2.5. Color measurement

Dyed samples were prepared for color measurements, which was carried out by the following a standard procedure. Color values were evaluated by mean of *K*/*S* v/s CIE Lab-color difference values (illuminant D 65/10°, observer) on Spectra Flash SF 650X spectrophotometer with data match Color Tools 3.1.2 software (Data Color International, USA). Four measurements were made on each of the four samples and the variation in the percentage reflectance values over range of 400–700 nm was recorded.

2.6. Determination of fastness

Wash fastness tests were carried out according to the ISO-105-C10 2006 (E) method. A specimen of the textile in contact with one or two specified adjacent fabric is mechanically agitated under specified condition of time 30 min and 50 °C for temperature in a soap, or soap and soda solution, then rinse and dried. The change in color of the specimen and the staining of the adjacent fabric, were assessed with the reference to the original fabric, using the grey scale or instrumentally. Light fastness tests were carried out according to AATCC method 16-E 1993 on a Ci 3000$^+$ Weather-O-meter (USA, Chicago) for 100 h. The changes in color of the samples were assessed against the appropriate blue wool scale for fading.

3. Result and discussion

Using different concentrations of mordant dyeing the *K*/*S* and CIE Lab values of the dyed wool fabrics (2% and 5% shades) are tabulated in the separate tables. The d-block elements form complex with tea, the amino group of wool fabric, and show the different shades.

The graphical presentation to show the metal ions effect of Alum, Cu and Fe with 5%, 10% solution in different standard dyeing method with natural dye (tea) for 2% and 5% shade (see Figs. 1 and 2).

The graphical presentation is clearly showing that the use of copper ion as mordant is very effective to enhance the shade depth of color during all dyeing process (see Figs. 3 and 4).

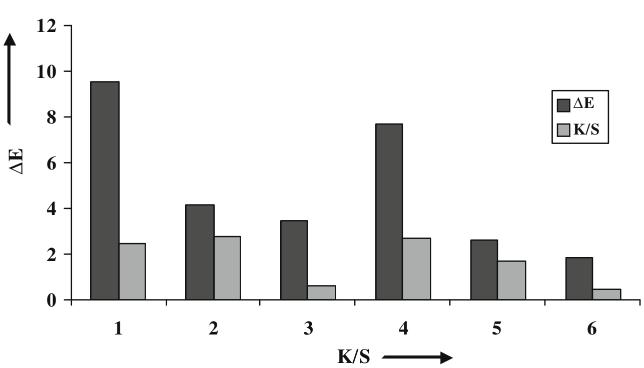

Figure 1 *K*/*S* and Δ*E* values of 2% shade of tea on wool fabric by pre-mordanting method.

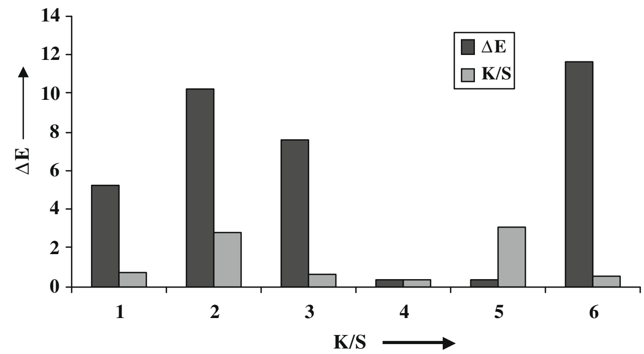

Figure 2 *K*/*S* and Δ*E* values of 2% shade of tea on wool fabric by meta-mordanting method.

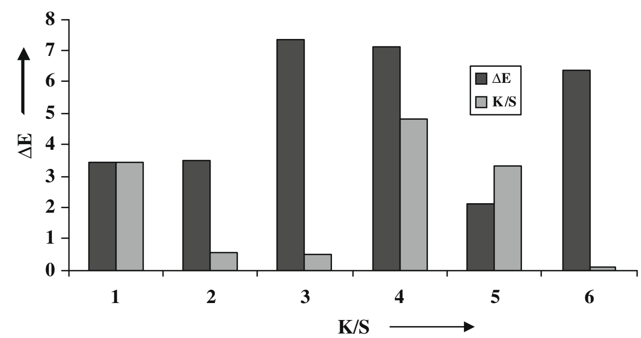

Figure 3 *K*/*S* and Δ*E* values of 2% shade of tea on wool fabric by post-mordanting method.

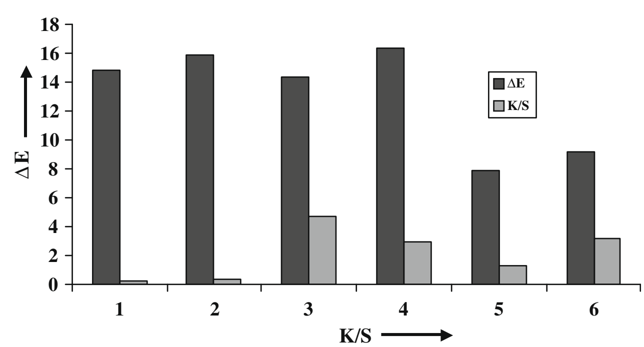

Figure 4 *K*/*S* and Δ*E* values of 5% shade of tea on wool fabric by pre-mordanting method.

4. Formation of color with different metal mordant

4.1. Group-1 (sodium and magnesium)

These metal ions did not have any tendency to from coordinate complexes. They can form only ionic bonds with the tea dye. Hence the dyeing produced tends to have only moderate *K*/*S* and CIE Lab values. Light fastness and wash fastness properties of natural dye with sodium and magnesium ions were very poor due to formation of week bonding between the dye molecule and the fibre (see Tables 1, 1a, 1b, 2a).

Table 1 *K/S* and CIE Lab values of original shade for 2% and 5%.

Dye ID #	L^*	a^*	b^*	C^*	h	ΔE	x	y	K/S	G.S
2% Original shade	54.98	9.90	22.35	24.44	66.10	0.50	0.3968	0.3803	10.50	5.0
5% Original shade	50.27	12.93	27.66	30.53	64.95	0.17	0.4246	0.3922	17.50	5.0

Table 1a *K/S* and CIE Lab values of 2% standard shade for pre-mordanting (M).

Mordant	L^*	a^*	b^*	C^*	h	ΔE	x	y	K/S	G.S
2% (M – 5% Alum)	47.79	10.69	22.25	24.69	64.34	9.57	0.4077	0.3835	2.45	4.0
2% (M – 10% Alum)	46.16	9.66	20.98	23.09	65.27	4.18	0.4036	0.3828	2.80	4.0
2% (M – 5% $CuSO_4$)	47.73	6.71	20.21	21.30	71.63	3.44	0.3917	0.3843	0.60	2.0
2% (M – 10% $CuSO_4$)	42.76	6.33	19.291	20.30	71.84	7.73	0.3941	0.3860	2.70	3.0
2% (M – 5% $FeSO_4$)	33.73	2.29	5.34	5.81	66.81	2.58	0.3418	0.3492	1.70	2.0
2% (M – 10% $FeSO_4$)	38.88	2.10	6.19	6.54	71.24	1.84	0.3417	0.3509	0.50	3.0

Table 1b *K/S* and CIE Lab values of 2% standard shade for meta-mordanting (Mm).

Mordant	L^*	a^*	b^*	C^*	h	ΔE	x	y	K/S	G.S
2% (Mm – 5% Alum)	50.59	8.57	21.24	22.91	68.02	5.22	0.3954	0.3826	0.70	2.0
2% (Mm – 10% Alum)	46.16	0.66	20.98	23.09	65.27	10.18	0.4036	0.3828	2.80	4.0
2% (Mm – 5% $CuSO_4$)	48.90	6.66	20.45	21.51	71.98	7.55	0.3905	0.3842	0.60	3.0
2% (Mm – 5% $CuSO_4$)	40.60	6.58	19.96	21.10	71.75	0.36	0.4000	0.3895	0.36	4.0
2% (Mm – 5% $FeSO_4$)	47.75	3.10	8.13	8.71	69.11	0.31	0.3482	0.3530	3.10	3.0
2% (Mm – 10% $FeSO_4$)	38.88	2.10	6.19	6.54	71.24	11.67	0.3417	0.3509	0.50	3.0

4.2. Group-2 (aluminum)

These metals formed weak coordination complexes with the dye, tendency to form quite strong bonds with the dye but not with the fibre. This is in accordance with the observed highest *K/S* values in present of aluminum. But, the appearance of shade dark brown with light shine, there was no big difference in the depth of shade or depth of color. They blocked the dye and reduced its interaction with the fibre in the case of study during the light fastness and wash fastness test. The rating of grey scale was varied. The poor wash fatness property for 2% shade of 5% Alum in meta and post-mordanting method of wool fabric is 2.0 in Table 3c. The ionic bonding of aluminum with the fibre was weak as compare than Cu and Fe (Tables 3b and 3c) (see Figs. 5 and 6).

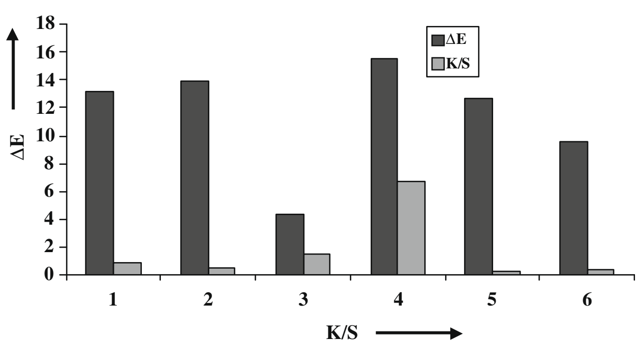

Figure 5 *K/S* and ΔE values of 5% shade of tea on wool fabric by meta-mordanting method.

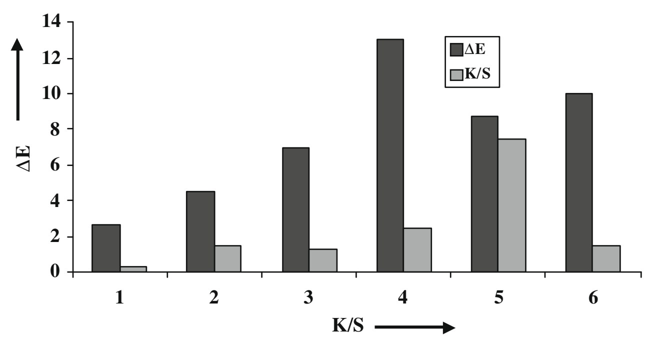

Figure 6 *K/S* and ΔE values of 5% shade of tea on wool fabric by post-mordanting method.

4.3. Group-3 (copper, iron and zinc)

Dyeing produces using these two mordant exhibited the highest *K/S* values. Both these metals are well known for the ability to from coordinate complex, and in this study both readily chelated with the dye, as the coordination number of copper and iron are 4 and 6, respectively. Some co-ordination sites remained un-occupied when they interacted with the fibre, amino group, attached with wool fibre occupied these sites. Thus these metals formed a binary, complex with the fibre with dye. Such a strong coordination tendency enhanced the interaction between the fibre and the dye, resulting in the high dye uptake. Since copper complexes are normally much stronger than those of iron, fabric-mordant-dye interactions were found stronger when using copper mordant, resulting in higher *K/S* values. For 2% (PM)–10% $CuSO_4$ for standard shade is the

Table 1c *K/S* and CIE Lab values of 2% standard shade for post-mordanting (PM).

Mordant	L^*	a^*	b^*	C^*	h	ΔE	x	y	K/S	G.S
2% (PM – 5% Alum)	50.12	10.32	22.54	24.7	65.39	3.44	0.4043	0.3833	3.45	2.0
2% (PM – 10% Alum)	56.43	7.45	21.93	23.1	23.16	3.50	0.3886	0.3818	0.55	2.0
2% (PM – 5% $CuSO_4$	47.74	7.51	19.61	21.0	69.05	7.33	0.3919	0.3812	0.50	3.0
2% (PM – 10% $CuSO_4$)	46.75	7.29	20.56	22.0	70.73	7.15	0.3963	0.3859	4.80	3.0
2% (PM – 5% $FeSO_4$)	47.23	2.00	8.57	8.80	76.88	2.12	0.3451	0.3561	3.30	2.0
2% (PM – 10% $FeSO_4$)	47.21	5.78	15.19	16.2	69.17	6.37	0.3748	0.3712	0.10	3.0

Table 2a *K/S* and CIE Lab values of light fastness of 2% shade of pre-mordanting (M).

Mordant	L^*	a^*	b^*	C^*	h	ΔE	x	y	K/S	LF
2% (M – 5% Alum)	46.80	9.79	22.25	23.38	64.34	5.47	0.4077	00.3828	2.45	5.0
2% (M – 10% Alum)	45.96	9.41	20.98	22.97	65.27	10.18	0.4032	0.3833	2.55	5.0
2% (M – 5% $CuSO_4$)	54.36	5.41	21.64	22.31	75.97	3.59	0.3917	0.3843	0.51	5–6
2% (M – 10% $CuSO_4$)	45.00	6.13	19.29	21.79	71.84	1.0	0.3941	0.3894	4.30	5–6
2% (M – 5% $FeSO_4$)	39.44	1.52	9.17	9.30	66.81	9.57	0.3418	0.3624	1.70	5.0
2% (M – 10% $FeSO_4$)	40.16	1.69	6.19	10.18	71.24	10.53	0.3532	00.3649	1.50	5.0

Table 2b *K/S* and CIE Lab values of light fastness of 2% shade of meta-mordanting (Mm).

Mordant	L^*	a^*	b^*	C^*	h	ΔE	x	y	K/S	LF
2% (Mm – (5% Alum)	53.95	7.18	21.49	22.66	71.53	2.76	0.3894	0.3827	0.90	5–6
2% (Mm – 10% Alum)	55.80	6.51	22.60	23.52	73.93	11.23	0.3889	0.3853	1.50	4.0
2% (Mm – 5% $CuSO_4$)	43.41	6.45	22.04	22.97	73.68	8.95	0.4022	0.3936	0.30	3.0
2% (Mm – 10% $CuSO_4$)	53.63	1.70	11.87	11.73	81.83	2.60	0.3507	0.3637	5.60	5–6
2% (Mm – 5% $FeSO_4$)	42.75	2.16	11.53	22.71	79.40	0.36	0.3577	0.3678	2.60	3.0
2% (Mm – 10% $FeSO_4$)	54.09	7.29	21.51	22.66	71.28	9.07	0.3895	0.3825	3.80	3.0

Table 2c *K/S* and CIE Lab values of light fastness of 2% shade of post-mordanting (PM).

Mordant	L^*	a^*	b^*	C^*	h	ΔE	x	y	K/S	LF
2% (PM – 5% Alum)	60.03	6.27	22.17	23.04	74.21	4.51	0.3832	0.3818	0.60	3.0
2% PM – 10% Alum)	54.13	7.91	22.85	24.17	70.91	4.71	0.3945	0.3851	3.20	3–4
2% (PM – 5% $CuSO_4$)	54.71	6.80	22.02	23.05	72.48	3.86	0.3891	0.3841	0.10	4.0
2% (PM – 10% $CuSO_4$)	49.26	6.31	21.20	22.12	73.43	0.24	0.3917	0.3965	4.0	5.0
2% (PM – 5% $FeSO_4$)	52.14	2.06	12.53	12.76	80.64	2.29	0.3542	0.3659	2.50	2.0
2%(PM – 10% $FeSO_4$)	51.41	4.75	17.42	18.05	74.74	10.80	0.3750	0.3767	0.45	3.0

best value of K/S = 4.80 and ΔE = 7.15 to show in Table 1c. Two percent shade for light fastness to show the best method of dyeing are pre-mordanting method with high value of blue wool scale rating = 5–6 (it slightly change in color). The depth of color to show the K/S values is 4.30 and ΔE = 1.0 of 10% $CuSO_4$ in Table 2b. But 5% (Mm) and 10% (PM) $FeSO_4$ also showed the poor light fastness rating that is 2–3 in Tables 2b and 2c). The reason is that, Fe metal ion is broken the bonding

Table 3a *K/S* and CIE Lab values of wash fastness of 2% shade of pre-mordanting (M).

Mordant	L^*	a^*	b^*	C^*	h	ΔE	x	y	K/S	WF
2% (M – 5% Alum)	44.98	9.08	21.87	23.68	67.46	9.76	0.4065	0.3872	1.30	3.0
2% (M – 10% Alum)	45.96	9.41	20.96	22.97	65.81	10.18	0.4032	0.3833	2.55	5.0
2% (M – 5% $CuSO_4$)	46.83	7.51	21.72	22.98	70.92	2.30	0.3993	0.3880	5.30	5.0
2% (M – 10% $CuSO_4$)	39.08	7.64	19.19	21.32	69.02	0.25	0.4053	0.3888	4.50	3.0
2% (M – 5% $FeSO_4$)	32.87	4.21	7.51	8.61	60.72	5.78	0.3572	0.3550	2.50	3.0
2% (M – 10% $FeSO_4$)	34.12	4.70	8.49	9.70	61.00	9.39	0.3614	0.3574	1.50	2.0

Table 3b *K*/*S* and CIE Lab values of wash fastness of 2% shade of meta-mordanting (Mm).

Mordant	L^*	a^*	b^*	C^*	h	ΔE	x	y	K/S	WF
2% (Mm – 5% Alum)	44.78	7.21	2023	21.47	70.39	3.42	0.36973	0.3861	4.50	2.0
2% (Mm – 10% Alum)	45.96	9.41	0.96	22.97	65.81	1018	0.4032	0.3833	2.55	5.0
2% (Mm – 5% $CuSO_4$)	46.98	8.13	22.13	23.58	69.84	7.55	0.4019	0.3880	1.70	3–4
2% (Mm – 10% $CuSO_4$)	38.51	7.59	20.02	21.41	69.23	0.71	0.4065	0.3897	4.70	3–4
2% (Mm – 5% $FeSO_4$)	46.10	5.48	11.85	13.06	65.17	6.40	0.3648	0.3620	1.80	2–3
2% (Mm – 10% $FeSO_4$)	40.16	1.69	10.04	10.18	80.46	11.32	0.3532	0.3649	1.50	3.0

Table 3c *K*/*S* and CIE Lab values of wash fastness of 2% shade of post-mordanting (PM).

Mordant	L^*	a^*	b^*	C^*	h	ΔE	x	y	K/S	WF
2% (PM – 5% Alum)	43.72	8.66	20.66	21.85	66.64	3.97	0.4016	0.3836	2.50	2.0
2% (PM – 10% Alum)	50.95	9.04	23.43	25.11	68.89	3.05	0.4026	0.3871	1.00	2–3
2% (PM – 5% $CuSO_4$)	45.14	9.13	20.42	20.43	65.90	4.83	0.4070	0.3828	3.0	3.0
2% (PM – 10% $CuSO_4$)	42.84	8.36	20.89	22.84	68.54	5.22	4.07	0.4058	6.40	4.0
2% (PM – 5% $FeSO_4$)	48.36	5.17	13.56	14.51	69.15	4.09	0.3674	0.3666	2.80	3.0
2% (PM – 10% $FeSO_4$)	44.24	7.70	17.33	18.96	66.04	13.73	0.4914	0.4122	2.50	2–3

Table 1a* *K*/*S* and CIE Lab values of 5% standard shade for pre-mordanting (M).

Mordant	L^*	a^*	b^*	C^*	h	ΔE	x	y	K/S	G.S
5% (M – 5% Alum)	45.55	12.65	22.88	26.14	61.07	14.82	0.4180	0.3834	0.30	4.0
5% (M – 10% Alum)	44.50	11.48	22.59	25.34	63.05	15.91	0.4158	0.3854	0.40	4.0
5% (M – 5% $CuSO_4$)	40.68	8.43	20.90	22.54	63.75	14.34	0.4297	0.3923	4.70	4.0
5% (M – 10% $CuSO_4$)	39.76	7.17	19.66	20.95	69.98	16.35	0.4021	0.3883	3.00	4.0
5% (M – 5% $FeSO_4$)	23.80	4.47	8.41	9.53	62.01	7.96	0.3617	0.3581	1.30	2.0
5% (M – 10% $FeSO_4$)	40.62	5.84	13.15	14.39	66.06	9.21	0.3752	0.3686	3.21	3.0

Table 1b* *K*/*S* and CIE Lab values of 5% standard shade for meta-mordanting (Mm).

Mordant	L^*	a^*	b^*	C^*	h	ΔE	x	y	K/S	G.S
5% (Mm – 5% Alum)	48.41	9.11	22.49	24.26	67.95	13.18	0.4035	0.3863	0.90	3.0
5% (Mm – 10% Alum)	48.37	10.76	35.50	25.85	65.40	13.89	2.92	0.4106	0.50	4.0
5% (Mm – 5% $CuSO_4$)	39.68	7.96	19.72	21.26	68.02	4.39	0.4046	0.3870	1.50	4.0
5% (Mm – 10% $CuSO_4$)	39.11	7.28	21.43	22.63	71.23	15.57	0.4092	0.3942	6.70	4.0
5% (Mm – 5% $FeSO_4$)	38.70	2.74	11.74	12.06	76.87	12.73	0.3633	0.3702	0.30	3.0
5% (Mm – 10% $FeSO_4$)	36.41	2.21	10.31	10.55	77.91	9.61	7.89	0.3586	0.40	2.0

Table 1c* *K*/*S* and CIE Lab values of 5% standard shade for post-mordanting (PM).

Mordant	L^*	a^*	b^*	C^*	h	ΔE	x	y	K/S	G.S
5% (PM – 5% Alum)	46.54	10.73	23.80	26.11	65.73	2.64	0.4142	0.3885	0.30	2.0
5% (PM – 10% Alum)	47.83	11.93	23.18	26.07	62.77	4.48	0.4134	0.3889	1.45	2.0
5% (PM – 5% $CuSO_4$)	45.26	8.95	23.05	24.76	68.82	6.94	0.4039	0.3907	1.30	2.0
5% (PM – 10% $CuSO_4$)	41.24	8.78	21.51	23.24	67.81	13.0	0.4103	0.3897	2.5	2.0
5% (PM – 5% $FeSO_4$)	42.41	6.92	17.86	18.99	68.91	8.75	0.3911	0.3803	7.50	1.0
5% (PM – 10% $FeSO_4$)	42.55	8.31	18.64	20.25	65.78	9.96	0.3972	0.3802	1.50	2.0

in the presence of light. The wash fastness properties of 2% shade of natural dye 5% $CuSO_4$ (pre-mordanting method) to show the excellent rating of grey scale is 5.0 mean there is no change in color or fading. The depth of shade also showed the highest *K*/*S* values is 5.30 and ΔE = 2.30 in Table 3a. The standard shade of 5% natural dye to used the best dyeing

Table 2a* *K*/*S* and CIE Lab values of light fastness of 5% shade of pre-mordanting (M).

Mordant	L^*	a^*	b^*	C^*	*h*	ΔE	*x*	*y*	*K*/*S*	LF
5% (M – 5% Alum)	46.15	10.67	23.06	25.40	65.17	15.47	0.4124	0.3869	1.40	4.0
5% (M – 10% Alum)	46.00	11.51	23.12	25.32	63.54	13.11	0.4150	0.3857	1.40	5.0
5% (M – 5% $CuSO_4$)	42.14	8.24	21.88	24.89	68.38	11.34	0.4051	0.3877	1.00	5.0
5% (M – 10% $CuSO_4$)	38.67	7.44	19.92	21.26	69.52	13.35	0.4054	0.3895	2.50	5.0
5% (M – 5% $FeSO_4$)	40.53	4.83	13.98	14.81	70.94	6.76	0.3752	0.3731	0.60	4.0
5% (M – 10% $FeSO_4$)	39.30	4.67	13.76	14.53	71.26	15.31	0.3754	0.3735	0.25	4.0

Table 2b* *K*/*S* and CIE Lab values of light fastness of 5% shade of meta-mordanting (Mm).

Mordant	L^*	a^*	b^*	C^*	*h*	ΔE	*x*	*y*	*K*/*S*	LF
5% (Mm – 5% Alum)	48.71	9.26	22.79	24.59	67.89	9.46	0.4043	0.3866	1.50	4.0
5% (Mm – 10% Alum)	48.42	11.05	24.31	26.70	65.55	1.71	0.4136	0.3880	2.40	4.0
5% (Mm – 5% $CuSO_4$)	39.16	6.41	20.72	21.68	72.81	16.30	0.4042	0.3936	1.20	5.0
5% (Mm – 10% $CuSO_4$)	38.46	7.41	22.32	22.88	71.10	15.71	0.4114	0.3953	1.7	5.0
5%(Mm – 5% $FeSO_4$)	39.51	2.89	12.13	12.65	76.76	5.80	0.3650	0.3714	2.50	3.0
5% (Mm – 10% $FeSO_4$)	37.77	7.45	11.21	11.47	77.69	6.06	0.614	0.3694	1.50	2.0

Table 2c* *K*/*S* and CIE Lab values of light fastness of 5% shade of post-mordanting (PM).

Mordant	L^*	a^*	b^*	C^*	*h*	ΔE	*x*	*y*	*K*/*S*	LF
5% (PM – 5% Alum)	46.76	10.07	24.57	26.56	67.71	13.78	0.4143	0.3916	1.0	5–6
5% (PM – 10% Alum)	49.44	9.69	23.06	25.02	67.20	9.87	0.3862	0.3862	2.0	5–6
5% (PM – 5% $CuSO_4$)	42.49	8.70	22.50	25.13	68.86	16.76	0.4112	0.3917	2.50	5–6
5% (PM – 10% $CuSO_4$)	39.81	8.19	21.39	22.90	69.05	16.75	0.4106	0.3917	2.50	5–6
5% (PM – 5% $FeSO_4$)	41.05	6.21	17.68	18.74	70.65	15.11	0.3909	0.3826	0.70	5–6
5% (PM – 10% $FeSO_4$)	42.13	7.38	17.71	19.17	67.37	16.56	0.3928	0.3797	0.70	5–6

Table 3a* To show the *K*/*S* and CIE Lab values of wash fastness of 5% shade of pre-mordanting (M).

Mordant	L^*	a^*	b^*	C^*	*h*	ΔE	*x*	*y*	*K*/*S*	WF
5% (M – 5% Alum)	38.91	8.58	18.92	20.77	65.61	5.58	0.4044	0.3880	3.50	1–2
5% (M – 10% Alum)	43.22	8.18	21.14	22.66	68.88	2.95	0.4195	0.3888	9.40	2.0
5% (M – 5% $CuSO_4$)	33.26	9.43	19.53	21.69	64.22	10.14	0.4102	0.3902	9.40	2.0
5% (M – 10% $CuSO_4$)	34.87	7.68	19.19	20.67	68.18	20.73	0.3861	0.3699	0.55	2–3
5% (M –5% $FeSO_4$)	35.06	7.17	13.18	15.0	61.47	8.80	0.3936	0.3729	3.90	2–3
5% (M – 10% $FeSO_4$)	35.32	8.06	14.55	16.63	61.03	16.08	0.4050	0.3839	0.95	2–3

Table 3b* *K*/*S* and CIE Lab values of wash fastness of 5% shade of meta-mordanting (Mm).

Mordant	L^*	a^*	b^*	C^*	*h*	ΔE	*x*	*y*	*K*/*S*	WF
5% (Mm – 5% Alum)	46.90	11.05	21.95	24.57	63.28	13.18	0.4098	0.3827	0.90	3–4
5% (Mm – 10% Alum)	50.65	12.45	24.19	27.21	62.77	14.08	0.4134	0.3889	0.25	3–4
5% (Mm – 5% $CuSO_4$)	40.26	7.28	20.47	21.73	70.43	4.33	0.4042	0.3902	1.50	4–5
5% (Mm – 10% $CuSO_4$)	37.33	7.45	20.71	22.01	70.21	15.57	0.4104	0.3933	6.70	4.0
5% (Mm – 5% $FeSO_4$)	36.90	3.20	8.01	8.62	68.25	6.83	0.3527	0.3568	3.25	3.0
5% (Mm – 10% $FeSO_4$)	32.10	1.36	4.13	4.35	71.73	3.01	0.3349	0.3463	3.30	2.0

method is meta-mordanting with 10% $CuSO_4$ to show the highest *K*/*S* value 8.70 and $\Delta E = 15.57$ in Table 1b*. For the light fastness shade of 5% to show the best dyeing method is post-mordanting with (5% and 10% $CuSO_4$) for blue wool scale rating 5–6, means there is some minor fading in it. The depth of shade mentioned in *K*/*S* value with ΔE values of in Table 2c*. The poor light fastness result of meta-mordanting method of 10% $FeSO_4$ for blue wool scale rating is 2–3, due

Table 3c* *K/S* and CIE Lab values of wash fastness of 5% shade of post-mordanting (PM).

Mordant	L^*	a^*	b^*	C^*	h	ΔE	x	y	K/S	WF
5% (PM – 5% Alum)	34.49	7.34	16.13	17.72	65.53	2.64	0.3986	0.3806	7.40	1.0
5% (PM – 10% Alum)	39.61	8.33	18.49	20.28	65.75	7.38	0.4017	0.3823	0.60	1–2
5% (PM – 5% $CuSO_4$)	35.72	7.44	18.79	20.21	68.40	6.94	0.4065	0.3885	4.40	1–2
5% (PM – 10% $CuSO_4$)	36.89	8.28	20.70	22.29	68.19	13.04	0.4137	0.3920	5.30	2–3
5% (PM – 5% $FeSO_4$)	34.40	9.88	19.61	21.96	63.27	8.75	0.4197	0.3874	4.40	1–2
5% (PM – 10% $FeSO_4$)	35.34	6.83	19.61	20.77	70.80	10.01	0.4081	0.390	3.95	3–4

to breaking of bonding in the during of 100 h. The wash fastness properties of natural dye (5% $CuSO_4$) is very good to show the grey scale rating is 5.0, there is no change in color or fading. The depth of color for 5% shade to show the *K/S* value11.50 and $\Delta E = 4.33$ in Table 3b*. The best result of dyeing method to show the good wash fastness properties of natural dye to used the meta-mordanting method. Zn are formed the coordinate bonding with the fibre, but not show the good result because due to some blockage of salt particle between the dye molecule and the fibre. Zn metal ion is not effective during the three different mordanting dyeing methods (see Tables 1a*, 1c*, 2a*, 2b*, 3a*, 3c*).

5. Conclusion

Aqueous extract of tea yield various brown shades on wool. The three dyeing method studied, post-mordanting method – gave the better depth of shade as well as superior wash and light fastness. In all cases the best results were achieved using copper salts as mordant. It is hinted at on the study basis that aqueous extract of tea that is environment friendly can be used to dye wool fabric using copper ions as mordant.

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