Colorimetric Analysis and Fastness Rating of Natural Yellow Color Dyes on Cotton Fabric

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Abstract

Today's environmental concern about the harmful effects of synthetic dyestuffs has arisen in our discourse on the use of natural dyes. Plant dyes are more favorable due to their non-toxicity, non-carcinogenic, non-allergic, and biodegradability over synthetic dyes to human beings. This work is intended to investigate the effects of three different natural yellow shaded dyes on the 100% cotton knit fabric using four kinds of synthetic mordant. A series of experiments were conducted to analyze and compare the results of these three sources of natural yellow dyes. Simultaneous extraction and dyeing methods were found to yield the best hues of yellow dye, as decided by colorimetric tests and visual analysis. The final samples were tested for fastness to light, wash, rubbing and perspiration by following the ISO standards. A significant change was observed in fastness properties and colorimetric analysis on copper sulphate treated turmeric dyed sample.

Keywords: Cotton fiber, Mordant, Natural Dye

1. Introduction

The coloration of textile materials (natural & synthetic) develops the look, appeal, and value of the product. Synthetic dyes were commercialized due to the limited resource of natural coloring substances. Natural dyes have organic value and eco-friendly application which has grown awareness among people towards the use of natural products over synthetic dyes. Vegetable dyes are very popular for coloring natural fibers, leather, and food substrate from ancient times [1]. Mordant is a chemical that improves the affinity and fastness properties of natural dyes. It forms a chemical bond with the natural fiber and helps in fixation [2]. Cotton is a cellulosic fiber that can easily be treated with natural dyes with the help of mordant. Turmeric is a plant dyestuff well known for its nontoxicity, harmless application for human beings [3]. And this turmeric has also been used for antibacterial dyeing of polyamide as a natural dye [6]. Natural dyeing with turmeric increases the value of textile products and meets the customers' wants for green products [4]. Marigold is a well-known flower plant all over the world. The yellow to orange-red extract of marigold finds a wide range of applications [2]. Orange peels, a wastage of most popular fruit orange find application as a low-cost natural dye for cotton [5]. The specific objectives of this study were to evaluate the effects of yellow color natural dye yields from turmeric, marigold flower, and orange peel to explore the possibilities of natural yellow dyes in terms of color value and fastness ratings as yellow is the liveliest and perhaps the most abundant of all hues in nature.

2. Methodology

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2.1 Materials:

Substrate:

A single jersey grey cotton knit fabric with 150 GSM was used for dyeing. And the fabric details were 52 courses per inch and 58 ends per inch.

Natural Dyes:

The natural dyes (turmeric, marigold & orange peel) were purchased from Gazipur, Bangladesh.

Mordant:

Four types of mordant: alum, ferrous sulphate ($FeSO_4$), potassium dichromate ($K_2 Cr_2 O_7$), and copper sulphate ($CuSO_4$) were collected from the textile laboratory of Northern University.

2.2 Methods:

2.2.1 Recipe of pretreatment

Sample- 15 gm
Alkali (NaOH) - 4 g/l
H_2O_2- 6 g/l
Stabilizer– 3 g/l
Wetting agent – 2 g/l
Detergent – 2 g/l
Sequestering agent – 2 g/l
Antifoaming agent – 0.5 g/l
Temperature – 100°C
Time – 1hour
M:L – 1:10

2.2.2 Recipe of dyeing (Using mordant)

Sample weight	: 10 gm
Dyes (Turmeric/ Marigold/ Orange peel)	: 40 ml
Mordant ($K_2Cr_2O_7$/ $CuSO_4$/ $FeSO_4$/Alum)	: 0.8 gm
Water	: 160 ml
Temperature	: 80°C
Time	: 1 hour

2.2.3 Recipe of dyeing (without mordant)

Sample weight	: 10 gm
Dyes (Turmeric/ Marigold/ Orange peel)	: 40 ml
Water	: 160 ml
Temperature	: 80°C
Time	: 1 hour

2.2.4 Pretreatment process

Scouring and bleaching of grey cotton fabric (15 gm) was performed in a sample dyeing machine by using sodium hydroxide (4gm/L), hydrogen peroxide (6gm/L), with wetting agent (2gm/L), sequestering agent (2gm/L), and stabilizer (3gm/L) at boiling temperature for one hour to remove the natural impurities and destroy the natural coloring matter from it.

2.2.5 Extraction of dyes

50g Turmeric, 50g Marigold flower, 50g Orange peel were separately subjected to aqueous extraction with 200 ml water for every dyestuff, Blender machine was used for crushing the dyestuff and heated for 30 minutes at 80^{o}C, and the refined extract was filtered separately and allowed to cool.

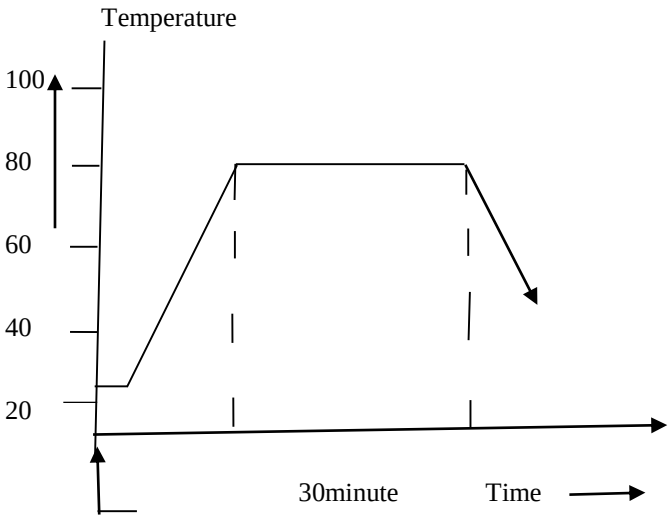

Figure 1. Extraction curve of dyes

2.2.6 Mordanting of pretreated cotton fabric

Scoured and bleached cotton fabrics were simultaneously mordanted with alum, $FeSO_4$, $CuSO_4$, $K_2Cr_2O_7$ at a similar concentration i.e., 8% per weight of the fabric. This mordanting was performed with dyeing in an exhaust dyeing machine.

2.2.7 Dyeing process

Cotton fabrics were dyed with the extracted dye solution from natural yellow color dyes at 80 °C for one hour following the M:L = 1:16 in a sample dyeing machine, which means that each of the 10 g cotton fabric was dyed with 160 ml extracted dye solution at the above-mentioned dyeing parameters.

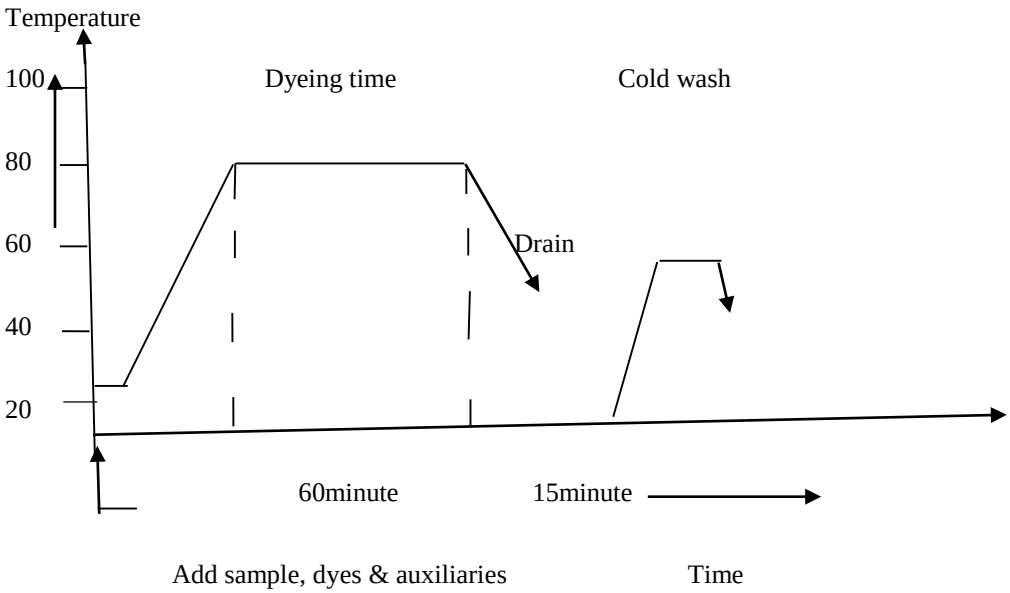

Figure 2. Process curve of dyeing

2.2.8 Different Testing Process after dyeing

Measurement of color co-ordinate

Through data color 650® Spectrophotometer, the color coordinate values of all dyed specimens were measured by following CIE Lab or CIE LCH method.
Where,
L*=Lightness/darkness value
a*=Red/Green axis, +a represents Redder, and –a represents Greener
b*=Yellow/Blue axis, +b represents Yellower, and -b represents Bluer
C*=Chroma, +ve represents brighter and -ve represents duller
h*= Hue

Measurement of Color strength:

The K/S value was assessed by a Spectrophotometer to observe the color strength of dyed samples which works on the Kubelka-Munk equation:

$$\frac{K}{S}=\frac{(1-R)^2}{2R}$$

Where R is the decimal fraction of the reflectance of dyed fiber.
K=light absorbed
S=light scattered

Evaluation of colorfastness to washing (ISO 105-C06-A2S)

To measure the colorfastness to wash properties of the dyed samples, the following parameters were maintained. To assess color change (ISO 105 A02) and color staining (ISO105 A03), standard grayscale was utilized to obtain ratings.

Assessment of wet and dry rubbing color fastness (ISO 105 X12:2016)

Dyed specimens were mounted on the crock meter and the finger of the crock meter was covered with a 5× 5 cm crocking cloth. The samples were rubbed with the finger of the meter at 10 turns within 10 seconds yielding 9±2 N pressure on fabrics. But for the wet rubbing test, this process was followed after soaking the fabric at 100% pickup.

Determination of lightfastness (ISO 105-B02)

The resistance of color of textiles to fade or bleed against light is called colorfastness to light. A Lightfastness tester was used to assess the fastness rating. Then the test specimen was compared with the blue scale or computer color matching system (CCMS).

Assessment of colorfastness to perspiration (ISO 105-E04)

The ability to resist change in color and stain in color against perspiration is called colorfastness to perspiration. Colorfastness test against perspiration of all dyed samples was measured in media like acid and alkali according to the ISO 105 E04 testing method. Then the assessment of the sample was performed.

3. Results and discussion

3.1 Visual appearance

The pictorial assessment of turmeric, marigold flower, and orange peel natural dyes when individually applied to cotton fabric samples using four different types of mordants following continuous mordanting technique is tabulated in Table 1. From the visual assessment, it has been found that among the three dyestuff, Turmeric dyestuff gave the best yellow shade with the mordants copper sulphate and alum. But it was observed that among all mordants, Copper sulphate exhibited the best properties as a mordant on cotton fabric for yellow shade in Turmeric dye. Likewise, alum worked well with marigold flowers whereas ferrous sulphate was found better in orange peel color.

Table 1. Image of yellow shade natural dyed cotton sample with and without mordant.

Sl. No.	Dyestuff	Mordant	Shade
S-1	Turmeric	Without Mordant	
S-2	Turmeric	$K_2Cr_2O_7$	
S-3	Turmeric	$FeSO_4$	
S-4	Turmeric	$CuSO_4$	

S-5	Turmeric	Alum	
S-6	Marigold	Without Mordant	
S-7	Marigold	$K_2Cr_2O_7$	
S-8	Marigold	$FeSO_4$	
S-9	Marigold	$CuSO_4$	
S-10	Marigold	Alum	
S-11	Orange Peel	Without Mordant	
S-12	Orange Peel	$K_2Cr_2O_7$	
S-13	Orange Peel	$FeSO_4$	
S-14	Orange Peel	$CuSO_4$	
S-15	Orange Peel	Alum	

3.2 Color co-ordinate value

From Table 2, it can be seen that samples S_4 and S_5 dyed with turmeric dyes using copper sulphate and alum as mordant describes brighter yellow shade than with other two mordants under D_{65} illuminant. Similarly, for marigold dyes, the value b* of the S_{10} sample exhibits a better depth of yellow color than the other three mordant treated cotton samples. Likewise, for orange peel dyes, the color value indicates that the use of ferrous sulphate provides a brighter yellow shade in the case of the S_{13} sample. Comparatively, without mordant S_1 presents an excellent shade than the other two sources of natural yellow color.

Table 2. CIE color coordinates of three natural dyed samples (Turmeric, Marigold, and Orange peel).

Sample no.	Illuminant	L*	a*	b*	c	h
S-1	F11	82.17	4.51	39.19	39.45	83.44
	D65	80.21	5.24	35.16	35.55	81.53
S-2	F11	83.53	3.12	33.26	33.41	84.64
	D65	81.93	3.33	29.72	29.91	83.6
S-3	F11	82.44	4.13	32.21	32.48	82.69
	D65	80.81	4.62	28.71	29.08	80.86
S-4	F11	80.02	3.58	63.59	63.69	86.78
	D65	77.47	4.2	58.02	58.17	85.86
S-5	F11	79.27	7.03	57.88	58.31	83.07
	D65	76.62	8.2	52.29	52.93	81.09
S-6	F11	74.62	3.09	20.17	20.4	81.28

	D65	73.87	2.41	18.07	18.23	82.39
S-7	F11	90.83	-0.08	7.17	7.17	90.63
	D65	90.62	-0.73	6.45	6.49	96.47
S-8	F11	77.84	1.73	10.13	10.28	80.32
	D65	77.4	1.4	9.07	9.17	81.25
S-9	F11	78.49	2.68	27.4	27.53	84.41
	D65	77.29	2.21	24.39	24.49	84.83
S-10	F11	75.2	4.07	33.62	33.87	83.1
	D65	73.81	3.56	30	30.21	83.24
S-11	F11	93.01	0.06	4.96	4.96	89.33
	D65	92.84	-0.32	4.5	4.51	94.07
S-12	F11	91.38	-0.17	6.95	6.95	91.39
	D65	91.2	-0.91	6.27	6.33	98.26
S-13	F11	82.56	5.3	29.02	29.5	79.65
	D65	81.02	5.72	25.62	26.25	77.41
S-14	F11	88.17	-1.18	14.69	14.73	94.59
	D65	87.71	-2.26	13.23	13.42	99.69
S-15	F11	91.78	-0.05	10.58	10.58	90.29
	D65	91.39	-0.69	9.52	9.54	94.15

3.3 Evaluation of color strength value

The color strength value of sample S_4 is higher than all other samples colored with three different sources of natural yellow dyes. The mostly light-yellow shade was achieved for the S_4 sample treated with $CuSO_4$ mordant and a dark shade of turmeric yellow hues with alum obtained for the S_5 sample. Untreated sample S_1 shows better color strength for turmeric dyes.

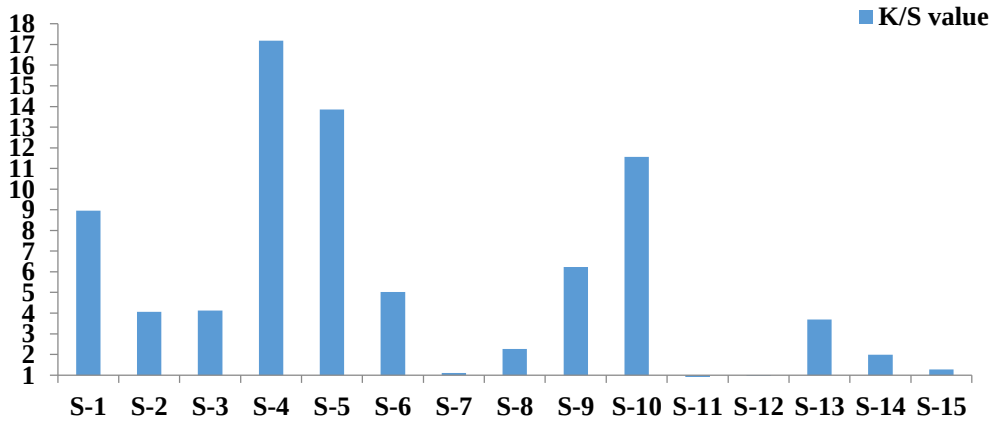

Figure 3. Color strength value of the natural yellow color dyed sample.

3.4 Colorfastness to wash

In the colorfastness to wash test, it has been found that the color change rating of S_4 & S_5 was poorer than other samples although the color value of these two samples falls in the darker yellow region. Color staining of the S_3 sample defines a fair wash fastness rating. Sample S_9, sample S_{13} & another two samples address the yellow region of color space and provide good fastness against color staining but poor to fair result was achieved for S_9 and S_{13} samples.

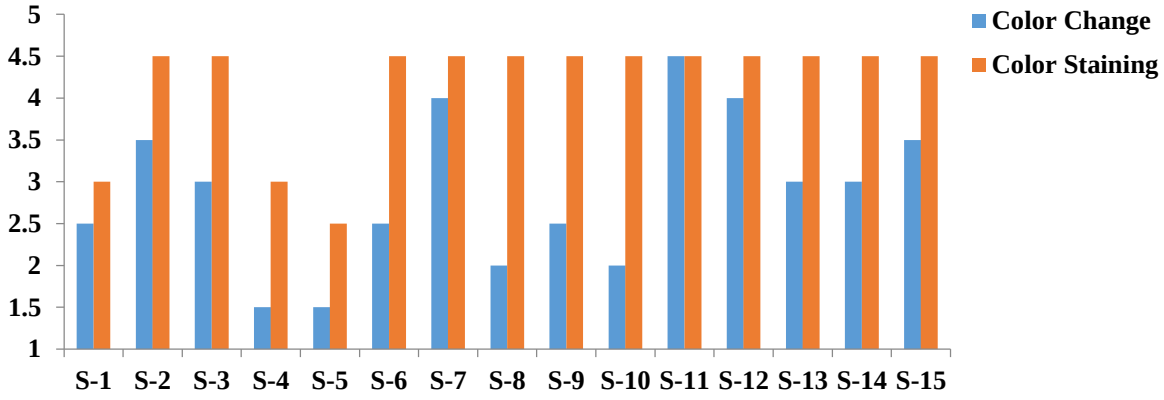

Figure 4. Rating of colorfastness to the washing test result of dyed samples

3.5 Colorfastness to rubbing

It was a noticeable matter that dyeing individually by three natural dyestuffs with different mordants gave excellent rubbing fastness results. Sample S_4, S_5, S_9, and S_{10} exhibit good to excellent dry rubbing fastness whereas wet rubbing was found to be fair to a good. Without mordant, samples S_1, S_6 and S_{11} show excellent dry and wet rubbing performance.

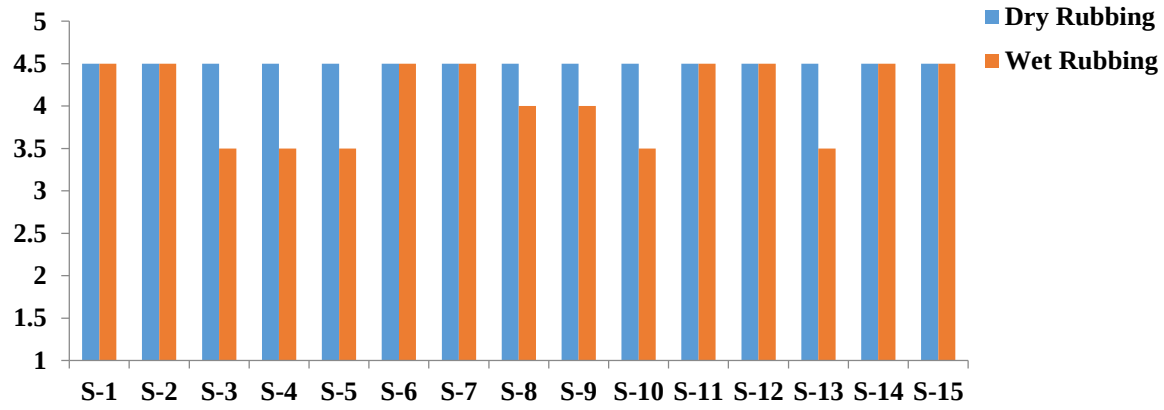

Figure 5. Rating of colorfastness to the rubbing test result of dyed samples

3.6 Colorfastness to perspiration

In the colorfastness to perspiration test, a good fastness rating against acid and alkaline perspiration were obtained for S_5, S_9, and S_{13} samples. Here sample S4 has shown a poor rating of perspiration fastness. Without mordant, samples S_1, S_6 and S_{11} give a good effect in colorfastness to perspiration.

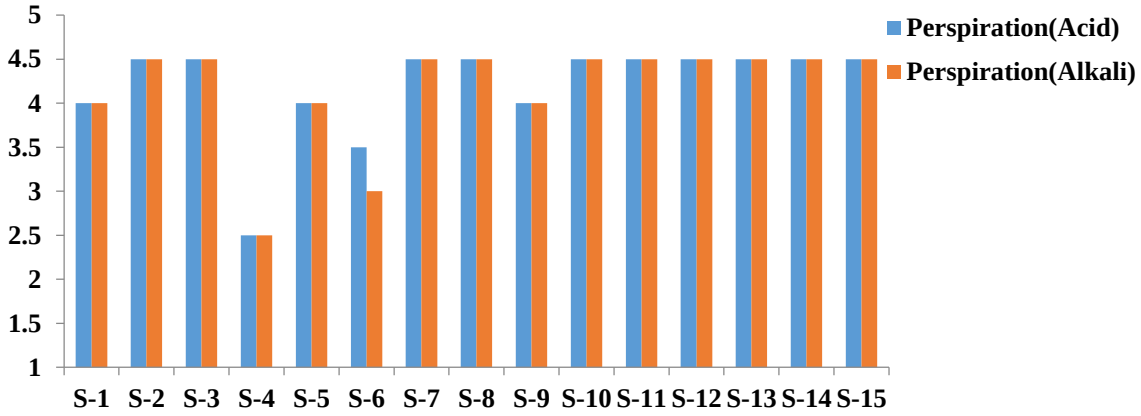

Figure 6. Rating of colorfastness to the perspiration test result of dyed samples

3.7 Colorfastness to light

Without mordant of cotton fabric dyeing with turmeric dyestuff gave very poor result. But sample S_3, S_4, S_9, and S_{13} indicate good ratings against the light. Here copper sulphate acts as a very good mordant for this sample.

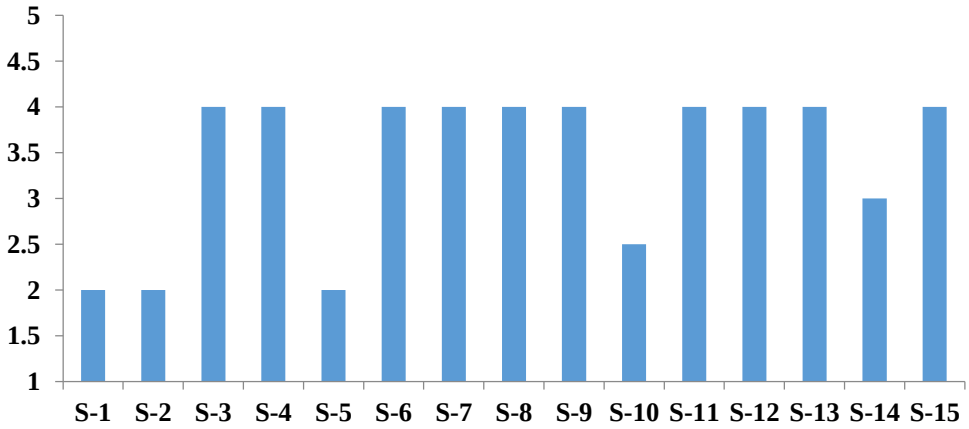

Figure 7. Rating of colorfastness to the light test result of dyed samples

4. Conclusion

This work has been conducted to analyze the yellow hues extracted from natural turmeric, marigold, and orange peel sources on 100% cotton knit fabric. Four different types of inorganic substances (copper sulphate, ferrous sulphate, alum, and potassium dichromate) have been used as mordanting agents or fixing agents, resulting in greater depth of shade and colorfastness. Without any mordant, the natural yellow hue was found on cotton fabric for turmeric dyes. Likewise, marigold and orange peel didn't produce any color on cotton in the absence of mordanting agents. Applying turmeric with four different mordants changed the yield of yellow hues. Sample S_4, S_5, S_{10}, and S_{13} produce a different

depth of yellow shade on cotton by creating a larger complex with mordanting agents. Copper sulphate and alum with natural turmeric yield the best results among all the samples. But the light, perspiration, and rubbing fastness properties show improvement while washing fastness exhibits deterioration. Furthermore, most of the fastness properties of this natural dye are poor, but somewhat comparable when the fabric is treated with mordants. Alum and copper sulphate considers as the best mordant for turmeric and marigold dyes and ferrous sulphate for orange peel dyes.

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