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Effect of various dyeing conditions on pure natural yellow dye from Turmeric for dyeing of wool yarn

Dr Mamta Vashishtha
Associate Professor, Amity school of Fashion Technology,
Amity University, Jaipur, Rajasthan, India

ABSTRACT

Turmeric Curcuma Longa is a perennial herb from ginger family, Zingiberaceae. It is native to southern Asia, requiring temperatures between 20 and 30 °C (68 and 86 °F) and a considerable amount of annual rainfall to thrive. Rhizomes of turmeric are used for extracting yellow dye for food and clothing. The present study was conducted at Department of clothing and textiles, G B pant university of Agriculture and Technology to develop 100% natural yellow colour for dyeing of wool without the use of any synthetic materials as mordants. Wool yarn was dyed with Turmeric at various concentrations, time durations and temperatures using different methods of dyeing. Different variables standardized were; Method of dyeing, concentration of dye material, temperature for extraction, temperature for dyeing, time for extraction and time for dyeing. The dyed samples were evaluated for colour fastness to light and washing as per ISO standards at the Department of textile technology, IIT Delhi.

Keywords: *Turmeric, curcumin, eco friendly dyes, wool, "Simultaneous extraction and dyeing"*

1. INTRODUCTION

Synthetic dyes are produced at high temperature and pressure from chemicals isolated from petroleum derivatives. During the manufacturing process of dyes many carcinogenic chemicals are used which leads to formation of toxic bi-products. These bi-products are discharged in the rivers, ponds or left in open. Hence cause severe atmospheric pollution (Paul R, 1996). This has threatened the ecological balance and called attention of the environmentalists to develop eco-friendly technologies to produce dyes from natural sources (Neelam Pruthi, 2007). The present study is aimed at developing 100% natural bright yellow colour for dyeing of wool without the use of any synthetic stuffs as mordants. A number of shades were developed with good to excellent washing fastness, through variations in dyeing conditions only. No synthetic chemical was used at any stage. Various studies have been carried out by different scientists on turmeric dye. However optimizing the dyeing conditions for turmeric dye, using simultaneous dyeing and extraction technique for dyeing of wool, investigated in the present study have not been reported earlier.

MATERIALS AND METHODS

Collection of Raw materials and their preparation:

Plant materials: Common name: Turmeric, Botanical name: Curcuma Longa

Family: ginger family, **Zingiberaceae**. It is native to southern Asia, requiring temperatures between 20 and 30 °C (68 and 86 °F) and a considerable amount of annual rainfall to thrive (Image- III)

Part used: Rhizomes , When not used fresh the rhizomes are boiled for about 30–45 minutes and then dried in hot ovens after which it is ready for sale in market for further use as a colouring agent for food and dyes. Dried Turmeric Rhizomes were collected from the local market complex in G. B. Pant University campus, Pantnagar, Udham Singh nagar,

Uttarakhand. Rhizomes were dried in shade and pulverized in a powder form (Image: II)

Instruments:

- Wiley mill installed in the department of Post Harvest Technology, College of Technology, Pantnagar was used for pulverizing the Turmeric Rhizomes.
- Optical density of dye solutions was measured by Spectrophotometer- G5866C installed in the department of Chemistry, College of Basic sciences and Humanities, Pantnagar.
- Electronic balance was used for weighing the dye materials and wool.
- Water bath with thermostatic temperature control was used for dyeing the wool samples in glass beakers under controlled conditions (Image: VI).
- Mercury Bulb Tungston fluorescent lamp (MBTF) Light fastness Tester installed at the department of Textile Technology, IIT Delhi was used to test the colour fastness of dyed samples to light.
- Atlas Launder'ometer installed in the department of Textile Technology, IIT Delhi was used for testing washing fastness of dyed samples (Image: IV)

Wool:
White Australian Merino wool was purchased from Shree Gandhi Ashram, Haldwani, Uttarakhand (Image I).

Blue Wool standards:
Blue Wool standards were used (for fading along with samples) for testing colour fastness to light (Image: VII).

Gray Scale:
- Colour fastness rating was done with Grey Scale for evaluating changes in colour and staining as per ISO recommendations (ISO 105-A02: 1993 and ISO 105-A-03) (Image: V).

Image I: The Un-dyed wool sample

Image II: Turmeric Rhizome and Powder

Image III: Inflorescence of Curcuma_longa_(Turmeric)

Image IV: Launderometer

Image V: Gray Scale

Image VI: The water Bath for Dyeing experiments

Processing of wool: The scouring of wool was done according to procedure mentioned by Hover 1976. A detergent solution of 1 ml of Genteel with 100 ml of hot water was prepared. When it was cooled to luke warm, skeins of wool were immersed. Theses skeins were stirred with a wooden spoon for 30 minutes. Later skiens were taken out, rinsed with lots of warm water. This treatment was repeated for three to four times, every time the detergent quantity was reduced. The skiens were squeezed and rinsed with tap water, till they were freed of the traces of detergent (care was takennot to scrub wring or mingle the skeins as it might cause hardening and matting of wool). Washed skeins of wool were allowed to dry and finally weighed for further experimentation.

Optimization of different variables:

A series of experiments were conducted in order to standardize the different variables; such as dyeing technique, concentration of the dye material , time for extraction of dye, time for dyeing, temperature for extraction and temperature for dyeing.

For dyeing of samples the MLR (material liquor ratio) selected was 1:10. The Optical density (OD)values of the dye solutions before and after dyeing were recorded. A sample of one ml was taken from each beaker and optical density was recorded by diluting it 20 times. The percent absorption was calculated by the following formula:

% Absorption = OD before dyeing – OD after dyeing / OD before dyeing X 100

Dyed samples were judged by a panel of 15 judges visually on the criteria of luster, evenness of dye, depth of shade and overall appearance. From the total marks obtained the percentage ratings were calculated. Each optimized variable was used in further experiments where ever desired.

The final range of shades was tested for colour fastness to light and washing at the Department of Textile Technology, IIT Delhi.

Dyeing Techniques:

Technique I:

Turmeric powder was tied in muslin bags (2 inch X 2 inch) with a thread to hold it. Pre soaked and weighed wool sample, and dye bag were put in a beaker containing 100 ml water. Beaker was placed in a boiling water bath (100ºc). Simultaneous extraction and dyeing was carried out in glass beakers for one hour.

Samples were stirred and dye bags were pounded with a glass rod after every five minutes to ensure even dyeing and continuous extraction of dye from muslin bag. After one hour dye bags were taken out and dyed samples were allowed to cool in dye bath itself. Then the samples were rinsed under running water and dried in shade.

Technique II:

In this technique the conventional method of dyeing has been used. The dye was extracted for one hour in a boiling water bath (100ºc). The solution was then cooled and filtered. Pre soaked wool sample of 10 g was added to this dye solution and dyeing was carried out at 80ºc for one hour. The samples were stirred with glass rod after every 10 minutes in order to obtain an even dyeing on sample. After one hour beakers were taken out of water bath and samples were allowed to cool in dye bath itself. Dyed samples were then rinsed under tap water and dried in shade.

According to results obtained Technique I was selected for Turmeric dye. For further experiments Technique I was used.

Measuring the Optical density while using Technique I

During further experiments while using technique I, each experiment was carried out as a pair of two. In each pair of two beakers, two dye bags with same contents and water were placed but presoaked weighed wool sample was added only to one beaker and both beakers were placed in dye bath for extraction and dyeing. This was done in order to facilitate recording of the optical density before and after dyeing. Thus for each experiment the number of specimen dye solutions was doubled. For example For

optimization of concentration 3 different concentrations i.e. 1g, 2g, & 3g were tested. Two bags for each quantity- total 6 dye bags were placed in separate beakers to carry out the experiment.

Concentration of dye material:

For optimization of concentration of Turmeric dye, 3 different concentrations i.e. 1g, 2g, & 3g were tested, Simultaneous extraction and dyeing was carried out for one hour at 100ºc. The remaining process was repeated as explained earlier. Optical density was measured for all six solutions and dyed samples were evaluated by judges.

Time for simultaneous extraction & dyeing:

Simultaneous extraction and dyeing was carried out with optimized concentration, for three different time durations i.e. 60, 120, 180 minutes respectively at 100ºc. Rest of the procedure was done as mentioned earlier. Optical density was measured for all six solutions and dyed samples were evaluated by judges.

Temperature for simultaneous extraction & dyeing:

Simultaneous extraction and Dyeing was carried out with optimum concentration of dye for optimized time duration at four different temperatures i.e. 40ºc, 60ºc, 80ºc, 100ºc. Optical density was measured for all eight solutions and dyed samples were evaluated by judges.

Preparation of Final samples:

Final sample was prepared by dyeing the presoaked weighed wool sample with Turmeric using all optimized variables i.e. optimized dyeing technique, optimized concentration of dye material, optimized time for extraction and dyeing and optimized temperature for extraction and dyeing. This sample was prepared for final tests to colour fastness and washing (Table- A)

As per the results of evaluation by judges the shades out of 13 shades were selected. Finally 9 different shades of yellow were included in the final range of shades (table- A). Further Tests of the final range of shades, for colour fastness to light and washing were done at the Department of Textile Technology, IIT Delhi.

Colour fastness Tests of dyed samples:

Colour fastness to Light: The dyed wool yarns were mounted on a 6 cm wide card board frame in asheet form (of parallel lengths) of 3x6 cm size. Along with these Blue wool standards were also mounted. A strip of thick black chart paper was pinned up so as to cover half portion of the specimen and standards. Thus samples half exposed were put inside Fadometer and faded as per ISO recommendations. The standards and specimen were checked after every few hours till a contrast between exposed and unexposed parts of specimen was equivalent to grade 3 on the Grey scale. The samples were compared with Blue wool standards and rated (Image VII).

Colour fastness to washing:

Yarns of test samples were made into sheet form of parallel length measuring 10x4 cm and placed between two pieces of undyed fabrics of same size. The fabric on one side was wool and on other side was cotton. These three layers were sewn from all sides to form a composite specimen (Image: VIII). Soap solution prepared for testing washing fastness had 5 ml of Genteel per liter. Each composite sample was treated in the Launder'o meter for 45 minutes at a temperature of 50 ± 2ºc. The liquor: material ratio was 50:1.The samples were removed from Launder'ometer, rinsed thoroughly under running tap water, dried and ironed.

The samples were graded on the basis of change in colour of the samples and also the staining of the adjacent fabrics with the help of Grey scales.

Evaluation of the samples for fastness to light and washing:

The rating of the samples for fastness to light and washing was done as follows;

Rating for colour fastness to light-

6	very good
5	Good
4	Fairly Good
3	fair
2	Poor
1	Very Poor

Rating for change in colour

5	Excellent
4	Good
3	Fair
2	Poor
1	Very Poor

Rating for staining

5	Negligible or no staining
4	Slightly stained
3	Noticeably stained
2	Considerably stained
1	Heavily stained

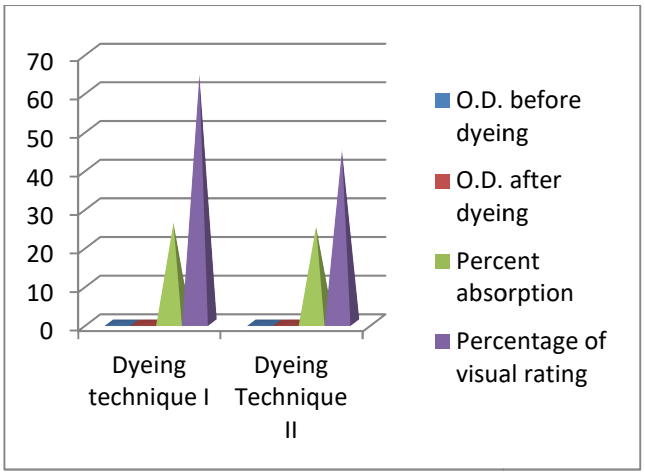
Image VII: Specimen showing contrast after light fastness Test

Image VIII: Specimen for Washing fastness Test (All 3 layers visible, specimen placed between cotton & wool fabric)

RESULTS AND DISCUSSION:

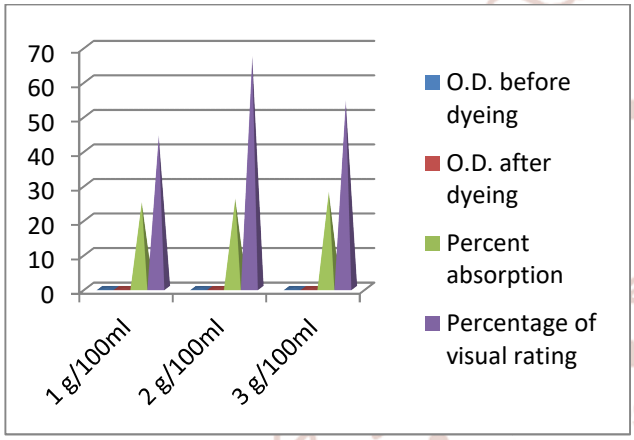
Turmeric is one of the oldest natural colouring agents used throughout the world from ancient times (Gulrajani M L). The rhizomes of the perennial turmeric are the source of colour. It is cultivated in almost all the parts of India Curcumin is the prime principal constituent of yellow dye, along with other constituents like monodesmethoxycurcumin and bidesmethoxycurcumin, which also contributes fewer amounts of pigment and flavour (GULRAJANI M L).

Under experimental trials, different methodologies were adopted for the extraction of colour and dyeing of wool. Figures and tables I to IV show the results of the experiments.



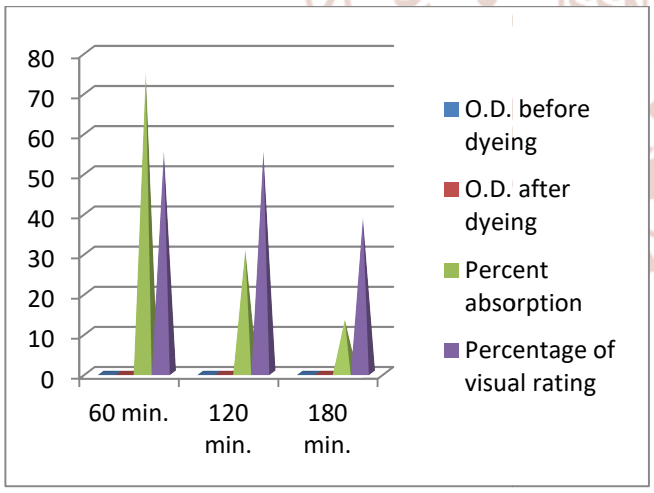
Dyeing Technique	O.D. before dyeing	O.D. after dyeing	Percent absorption	Percentage of visual rating
Dyeing technique I	0.27	0.2	25.92	64.33
Dyeing Technique II	0.2	0.15	25	44.83

Figure I & Table I: Percentage ratings of visual analysis and dye absorption percentage with different methods of dyeing for Turmeric (wave length- 380 nm)



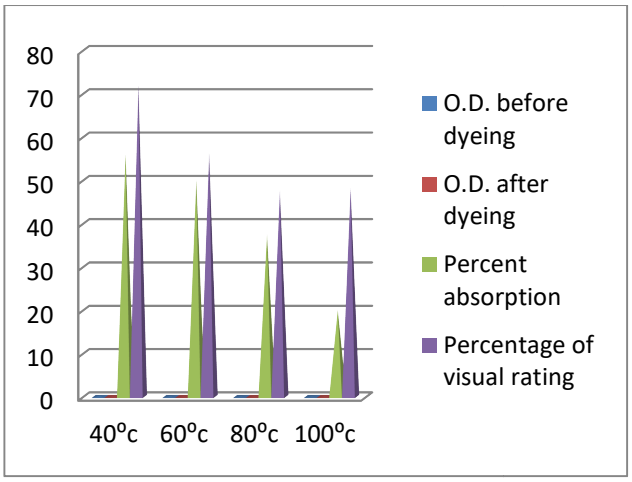
Conc. Of dye (g/100ml)	O.D. before dyeing	O.D. after dyeing	Percent absorption	Percentage of visual rating
1	0.24	0.18	25	44.33
2	0.26	0.19	26	67.33
3	0.25	0.18	28	54.5

Figure II & Table II : Percentage ratings of visual analysis and dye absorption percentage (at 380 nm) with different concentrations of dye for Turmeric



Time for simultaneous extraction and dyeing (min.)	O.D. before dyeing	O.D. after dyeing	Percent absorption	Percentage of visual rating
60 min.	0.16	0.04	75	55.5
120 min.	0.13	0.09	30.76	55.3
180 min.	0.15	0.13	13.33	38.83

Figure III & Table III : Percentage ratings of visual analysis and dye absorption percentage (at 380 nm) at different time durations for Turmeric dye



Temperature for simultaneous extraction and dyeing	O.D. before dyeing	O.D. after dyeing	Percent absorption	Percentage of visual rating
40°c	0.25	0.11	56	72
60°c	0.2	0.1	50	56.33
80°c	0.16	0.1	37.5	47.66
100°c	0.15	0.12	20	48.16

Figure IV & Table IV: Percentage ratings of visual analysis and dye absorption percentage (at 380 nm) at different temperatures for Turmeric dye

Figure I & table I show the results of colourimetric analysis (at 380 nm) and visual analysis at various parameters explained earlier. As per the results technique one was selected as appropriate for turmeric dye as this produced much better hue as compared to dyeing technique II. The water soluble yellow dye from turmeric rhizomes (Curcumin) is very fugitive in nature (Sachan & kapoor 2007). The hue becomes dull with exposure to time and temperature. The conventional aqueous extraction procedure involves a time gap between extraction of dye and actual dyeing of the substrate. This exposure to time gap makes the dye dull and unappealing. In "Simultaneous extraction and dyeing" the dyeing of substrate is carried out in same water bath along with extraction of dye from the raw material. This experiment was conducted to compare and analyze the results two different procedures of dyeing, by means of colorimetric analysis and visually by trained subject experts. Simultaneous extraction and dyeing method was found to yield best hues of yellow dye as decided by colorimetric tests and visual analysis. The colours are brighter and appealing as the dye is absorbed by the substrate as soon it is released in water bath.

Fig II & table II reveal the results of optimization of concentration of Turmeric dye. According to results 2gms of Turmeric per 100 ml of water, for dyeing 10 gm of wool was found as optimum concentration. Anshu (1987) has recommended that 2 gm of dye is required per gm of wool to obtain optimum colour from natural dye Turmeric. This is a bit different from findings of the present study i.e. 2 gm of Turmeric dye is required to dye 10 gm of wool. This variation in findings may be due to natural variation in sources of dyes used and also wool used. It's a well known fact that properties of natural products vary too much because of variation in environment and nourishment of the source used.

Results of colorimetric analysis and visual analysis (to optimize the time for dyeing) show that 60 min. dyeing time is appropriate for Turmeric. Maximum dye absorption was found at 60 min. duration (Table III and Figure III). Results show that dyeing beyond 60 min. makes the hue dull. The decrease in colour strength for 120 minutes of dyeing may be attributed to desorption of dye molecules as a consequence of over dyeing (Nagia F A & El- Mohamedi, 2007). Cavendish (1978) has reported that extraction time of natural dyes varies from 20 to 120 minutes. The observations of the present study fall within this range.

Fig IV and table IV show that 40°c temperature provides the best results for dyeing with Turmeric. Temperature beyond that made the hue more Greyish. The Dye absorption was also found maximum at 40°c. The results indicate that high temperature should be avoided for dyeing with turmeric if a bright hue is required. However Saima Umbreen et.al report that maximum colour strength is obtained at 90°c but dyeing is not uniform. (Umbreen Saima, 2008). This variation in findings may be due to natural variation in sources of dyes used and also procedures used. Even slight variations in environment, water, soil etc may cause variation in crops and products.

Various shades of yellow ie. Pale Dijon, Flaxen, Dijon, Dandelion yellow, Straw Yellow, Lion Yellow, Corn Silk, Ripe Hay, pale Flaxen were achieved through different dyeing procedures during optimization process. The optimized parameters were Dyeing technique I, conc. of dye 2%, temperature 40ºc, Dyeing time- 60 min.

Table B: Ratings for colour fastness to light and washing

SN	Sample	Ratings for Colour fastness to light	Colour fastness to washing		
			Ratings for colour change	Ratings for staining on cotton	Ratings for staining on wool
	Pale Dijon	2- 3	4	3-4	4
	Flaxen	3	5	4	4-5
	Dijon	2	4	3	4
	Dandelion Yellow	3	4-5	3-4	4
	Straw Yellow	3	3-4	5	3-4
	Lion Yellow	2	3	2	4
	Corn Silk	2	4	3-4	4
	Ripe Hay	3	5	4	4-5
	Pale Flaxen	2-3	4-5	4	4-5

Table B shows the results of color fastness tests to Light and Washing. Most of the shades exhibited poor to fair fastness to light. The samples were found to be affected by light rapidly. The shades processed at high temperature exhibited a bit better colour fastness to light. For shades done at high temperature a grade of 3 (fair) was observed. Over all the range of light fastness grades were between 2 to 3 (poor to fair).

Samples showed better grades for colour fastness to washing (3- 5). Best grades were observed for Flaxen, Ripe Hay and Pale flaxen (4- 5) good to excellent for change in colour, good for staining on cotton (4) & good to excellent for staining on wool. Lowest ratings were observed for Lion Yellow. Rest of the shades got a satisfactory rating of good to excellent (4-5) for colour change and staining as well.

CONCLUSION:

Today the protection of environment has become a challenge for the chemical industries world wide, All over the world the environment restrictions are becoming stricter. The need to realize the importance and the technology of natural dye is more urgent. This is then led to returning to traditional and more natural way of life (patel BH). Results of numerous experiments reveal that same dye produced different shades under different dyeing conditions. Standard recipes have been developed for each shade. A range of Flaxen to Dijon, Hay, straw, Dandelion, corn silk and Lion yellow were achieved (Table A). Observations proved that less temperature and reduced time of dyeing give better results in terms of colour appeal. Whereas analysis of the shade cards after a prolonged time gap shows that the high temperature and prolonged dyeing time produced shades with more durable dyeing. Thus any of the dyeing technique can be used as per the requirement of end product. These colours were used at Alps industries ltd. Ghaziabad, UP for dyeing cotton for their export orders. To improve the light fastness of these dyes, dyeing was carried out at fiber stage. Which improved the colour fastness to light up to grade 4 (a considerable improvement for colour fastness to light).

Experiments reveal that this dye can be used as a safe eco friendly dye. Numerous shades ; Pale Dijon, Flaxen, Dijon, Dandelion yellow, Straw Yellow, Lion Yellow, Corn Silk, Ripe Hay, pale Flaxen have exhibited good washing fastness and fair light fastness. There is a lot of scope to use the Turmeric dye for obtaining numerous colour shades .

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