

Green Dyeing of Silk Fabric with Turmeric Powder Using Tamarind Seed Coat as Mordant

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Abstract

The current study is aimed to explore the sustainable dyeing approach of silk fabric with turmeric powder using tannin as mordant extracted from tamarind seed coat. For that, tamarind seed coat tannin was extracted and applied as natural mordant alone and in combination with metal mordant namely copper sulphate for dyeing silk fabric with the extract of turmeric powder. Dyeing parameters such as temperature, time and mordant concentration were varying for optimizing the process. The color strength, color coordinates, color fastness to wash, perspiration, water and rubbing were evaluated for examining dyeing performance. Firstly, tannin was extracted from tamarind seed coat and applying on the silk fabric at 95°C temperature for 45 min by varying concentration. Among them 15 g/l shows better results. Some samples were mordanted with both 15 g/l extracted tannin and 0.5% copper sulphate solution. The mordanted samples were dyed with turmeric dye by varying the time and temperature. By analyzing the test results, the sample mordanted with extracted tannin showed high color strength and good fastness properties dyeing at 80°C for 60 min. The application of 0.5% copper sulphate mordant enhanced sustainable wash fastness properties.

Keywords

Tamarind Seed Powder, Tannin, Natural Mordant, Turmeric Powder, Silk

1. Introduction

Tannin is one in every necessary natural mordant commonly called bean tree which is one in every foremost necessary utile tree species within the Indian sub-continent [1] [2]. Coloration of textiles with natural mordant associated graded dyes was a recent specialty of history. As we are living in the modern age

of science and technology, trendy science and technology are developing day by day all-together with several advancements in textile innovations [3] [4]. The art of coloration was considered as early as of analysis [5] [6]. Throughout archeological excavations, numerous leftover unreal textiles throughout the planet provide confirmation to the act of coloring in ancient human civilizations [7]. From prehistoric time until the nineteenth century, natural dyes were used simply to textile coloration. Tamarind (*Tamarindus indica* L.) belongs to the family fabaceae (Leguminosae) subfamily Caesalpinioideae and most elements of this tree are found to be of some use [8] [9]. The utilization of fruit pulp has been well-known for awfully very long time. Different uses persist in food, chemicals and prescription drugs [10] [11]. The seed consists of half-hour exhausting however brown seed coat and seventy percent kernel. The kernels are separated from the seed coat either by preparation or by soaking the seeds in water. The poached or roast kernels can be eaten up and generally dried and grounded into flour for creating pan-cakes or mixed with rice. The kernels contain polysaccharides having an awfully sensible size property or utilized as a sizing agent for jute and textile yarns. Tamarind seeds inhibit the expansion of urinary crystals and are utilized in the treatment of patient's continual excretory organ stones [12]. The seed extract is additionally reportable to contain synthetic resin antioxidants and antimicrobial activity [13] [14]. The seed coat containing four-hundred water soluble matter is nothing however a mix of tannins. It is used for wound healing associated degreed as an anti-dysenteric drug. It is additionally used as a staple for the preparation of laminate adhesives [15] [16]. With a specific astringent style, the profile of polyphenolics gift within the tamarind seed coat was found to be dominated by proanthocyanidin, meaning a group of compounds shaped by the condensation or chemical change of flavan-3-ol or flavan-3,4-diol, normally called condensed tannins or phlorotannin [17].

Tannin is an astringent vegetable product found during a wide selection of plant components like bark, wood, fruit, fruit pods, leaves, roots and plant galls [18] [19]. Tannins are outlined as water soluble polyphenolic compounds of high relative molecular mass (about 500 - 3000) containing phenoplast radical teams to modify them to make effective crosslink between proteins and alternative macromolecules. They are primarily utilized in the preservation of animal skin, glues, stains and mordants [20] [21]. Meanwhile, natural fibres like cotton have terribly low affinity for many of the natural dyes. The tannins play a very important role in cotton coloring to retain coloring matter for good [22] [23]. The aim of getting ready the vegetable fibres with tannic acid isn't such a lot to mend the coloring matter, on fix bound gold-bearing salts like copper, iron, etc., within the sort of insoluble tannates [24]. The metal tannates bequest on the fabric forms insoluble lakes with the natural dyes throughout the coloring method and leads to improved fastness properties [25] [26]. Recently, thanks to increasing awareness of environmental problems and conjointly pollution made by artificial dyes, wide unfold interest has emerged within the coloring of textile fibres mistreatment natural colorants on account of their higher biodegradability [27]

and better compatibility with the atmosphere, comparatively low toxicity, repugnance. However, most analyses on natural dyes had been centered on the elemental aspects of the natural dyes just like the property of coloring, light fastness and wash fastness [28]. Very little attention, here coloring of silk using natural dyes extracted from natural plants wherever the name of natural dyes along with all the dyes derived from Turmeric (*Curcuma longa*).



Figure 1. Turmeric and powder form.

Indigenous to the Indian subcontinent and Southeast Asia, it needs temperature between 20°C and 30°C and significant annual rainfall to thrive. The plants are harvested annually for their roots and propagated from some rhizomes in the next season [29] [30]. If not used fresh, the rhizome is boiled in water for about 30 - 45 minutes, then dried in a hot oven and then ground to a deep orange-yellow powder (Figure 1), which is commonly used as a coloring and flavoring agent. It is used in many Asian cuisines, especially for curry and painting [31].

The findings of this work offer a new area of use for large amounts of seed coating, which are available as residual material during the production of tamarind seed powder, used as a sizing agent and silk dye with saffron powder dyes. Silk is a natural fiber extracted as filaments from silkworms. The most popular type of silk used worldwide is the silkworm collected from *Bombyx Mori* silkworms. Natural silk is a continuous filament of proteins rotated by silkworms. The spun silk is used in this research work. Although varieties of fabrics are available on the market, silk remains the queen of fabrics.

2. Experimental Methodology

In this research work following materials were used throughout:

2.1. Fabric

Degummed silk fabric was used in this project work which was collected from Bangladesh Sericulture Research and Training Institute, Rajshahi-6207. The fabric specification is as follows—(Plain weave, 50 EPI, 35 PPI, Warp count-25, Weft count-20, GSM-170).

2.2. Mordanting Materials

Tamarind (*Tamarindus indica* L.) seed coat was used as natural mordant which

was collected from local market of Tangail Town, Bangladesh. Copper sulphate (CuSO_4) was used as metallic mordant which was supplied by physical lab, Textile Engineering Department, MBSTU, Tangail, Bangladesh.

2.3. Colorants

Turmeric powder was used as natural colorants which were extracted from turmeric collected from local market of Tangail Town.

2.4. Separation of Tamarind Seed Coat for Extraction of Tannin

The tamarind seeds were dried in a hot oven at 100°C for 30 min. The coat was removed from the seeds by manual crushing and separated and then ground into powder form.

2.5. Tamarind Seed Husk

Tamarind seed husk is brown outer shell is obtained after roasting seeds and seed husk constitutes 35% of tamarind seed weight. Tamarind seed husk contains 20% - 23% fibers and high content of polymeric tannins. Tamarind seed husk used as biomass fuel and cattle feed.

2.6. Tanin Extraction Procedure

The finely powdered tamarind seed coat (200 g) was extracted with water (400 cc) for 2 hr at boil and then cooled. After cooling it was filtered through a fine muslin cloth and the filtrate was collected separately. The remaining residue was extracted three more times, in order to complete the extraction. The total extract (1600 cc) was heated to boil and was allowed to stand overnight and filtered again. The clear filtrate was concentrated using heating mantle. And then sample was treated with saturated brine NaCl solution. A brownish colored precipitate thus obtained was filtrated and dried in an oven to yield brown colored tamarind seed coat tannin in powder (**Figure 2**).



Figure 2. Separation of tamarind seed coat for extraction of tannin.

2.7. Extraction of Colorants

Turmeric colorant was extracted using water as the medium. Two grams of the colorants in the form of fine powder were mixed with 100 ml of water and allowed to soak for 30 min. Then the mixture was boiled for 60 min. The contents were cooled and filtered. The filtrate was used for dyeing.

2.8. Mordanting

Pre-mordanting technique was used for this study. For optimizing process, silk fabrics were treated with tamarind seed coat mordant solution using different concentration (5, 10, 15, 20 and 25) g/l and this treatment was carried out at 95°C for 45 min, keeping the liquor to material ratio 20:1. Among the concentration of mordant, we got 15 g/l as optimum concentration. The silk fabrics mordanted with 15 g/l tamarind seed coat mordant concentration were further treated with 0.5% (owf) copper sulphate (CuSO_4) solution at 85°C for 45 min, keeping the liquor to material ratio as 20:1. Silk fabrics, only mordanted with tamarind seed coat mordant and in combination with copper sulphate mordants, were squeezed and subjected to dyeing.

2.9. Dyeing Method

Dyeing was carried out in IR Dyer machine, physical lab, Textile Engineering Department, MBSTU, Tangail. For dyeing we kept the liquor to material ratio of 20:1. Pre-mordanted fabrics were introduced into the dyeing solution at room temperature and slowly the temperature was raised. For process optimization, we use different temperature for dyeing (40°C, 60°C, 80°C, 100°C). And finally 80°C was chosen as dyeing temperature. The dyeing was continued at 80°C temperature for different times (40 min, 50 min, 60 min, 70 min, 80 min, 90 min) and finally got 60 min as optimum time. After dyeing, the fabrics were rinsed and air-dried in flat dryer machine. Then, the soaping was done for removing unfixed dye from the fabric surface by 0.5 g/l ISO standard soap keeping the material: liquor ratio 1:10 at 70°C for 10 minutes. After soaping the samples were squeezed and air dried.

2.10. Fastness Measurement

In this research, the following fastness properties were measured [32] [33] [34] [35].

- Color fastness to wash (ISO 105 C04).
- Color fastness to water (ISO 105 E01).
- Color fastness to rubbing (ISO 105 X12).
- Color fastness to perspiration (ISO 105 E04).

2.10.1. Color Fastness to Wash (ISO 105 C04)

This test is carried out to evaluate the colorfastness to washing of textiles which are expected to withstand frequent wash. The fabric color loss and surface changes resulting from detergent solution and abrasive action of five typical

hand or home launderings, with or without chlorine, are roughly approximated by one 45 min test.

2.10.2. Color Fastness to Water (ISO 105 E01)

This test method is designed to measure the resistance to water of dyed, printed, or otherwise colored textile yarns and fabrics. Distilled water or deionized water is used in this test method because natural (tap) water is variable in composition.

2.10.3. Color Fastness to Rubbing (ISO 105 X12)

This test method is designed to determine the amount of color transferred from the surface of colored textile materials to other surfaces by rubbing. It is applicable to textiles made from all fibers in the form of yarn or fabric whether dyed, printed or otherwise colored. It is not recommended for use for carpets or for prints where the singling out of areas may be too small using this method. Test procedures employing white test cloth squares, both dry and wet with water, are given. As washing, dry-cleaning, shrinkage, ironing, finishing may affect the degree of color transfer from a material, the test may be made before, after or before and after any such treatment.

2.10.4. Color Fastness to Perspiration (ISO 105 E04)

This test method is used to determine the fastness of colored textiles to the effects of acid perspiration. It is applicable to dyed, printed or otherwise colored textile fibers, yarns and fabrics of all kinds and to the testing of dyestuffs as applied to textiles.

2.11. Color Differences Using CIE L*a*b* Coordinates

Defined by the Commission Internationale de l'Eclairage (CIE), the L*a*b* color space was modeled after a color-opponent theory stating that two colors cannot be red and green at the same time or yellow and blue at the same time. As shown below, L* indicates lightness, a* is the red/green coordinate, and b* is the yellow/blue coordinate. Deltas for L* (ΔL^*), a* (Δa^*) and b* (Δb^*) may be positive (+) or negative (-). The total difference, Delta E (ΔE^*), however, is always positive.

ΔL^* (L* sample minus L* standard) = difference in lightness and darkness (+ = lighter, - = darker)

Δa^* (a* sample minus a* standard) = difference in red and green (+ = redder, - = greener)

Δb^* (b* sample minus b* standard) = difference in yellow and blue (+ = yellower, - = bluer) [36].

2.12. Color Differences Using CIE L*C*H* Coordinates

The L*C*h color space is similar to L*a*b*, but it describes color differently using cylindrical coordinates instead of rectangular coordinates. In this color space, L* indicates lightness, C* represents chroma, and h is the hue angle. Chroma and hue are calculated from the a* and b* coordinates in L*a*b*. Deltas

for lightness (ΔL^*), chroma (ΔC^*), and hue (ΔH^*) may be positive (+) or negative (-). These are expressed as:

ΔL^* (L^* sample minus L^* standard) = difference in lightness and darkness (+ = lighter, - = darker)

ΔC^* (C^* sample minus C^* standard) = difference in chroma (+ = brighter, - = duller)

ΔH^* (H^* sample minus H^* standard) = difference in hue [36].

3. Results and Discussion

Silk fabrics were dyed with natural dyes extracted from turmeric in various condition with tamarind seed coat tannin and 0.5% concentrated Copper sulphate (CuSO_4) applied as mordanting agents to intensify the natural dye fixation. Influences of mordant concentration variation, time and temperature variation for color strength (CS) of selected samples were also examined. Dyeing performance of the dyed samples were assessed by evaluating several elementary parameters such as Color fastness to wash, Color fastness to rubbing, Color fastness to perspiration (alkaline and acidic) and Color fastness to water.

3.1. Effect of Tamarind (Mordant) Concentration Variation on K/S Values of the Dyed Fabric

Figure 3 shows that, K/S value of 15 gm/l mordant using sample is high than 5 gm/l, 10 gm/l and 20 gm/l mordant using sample. Lower values of the samples show that dye has lower substantivity towards the fabrics.

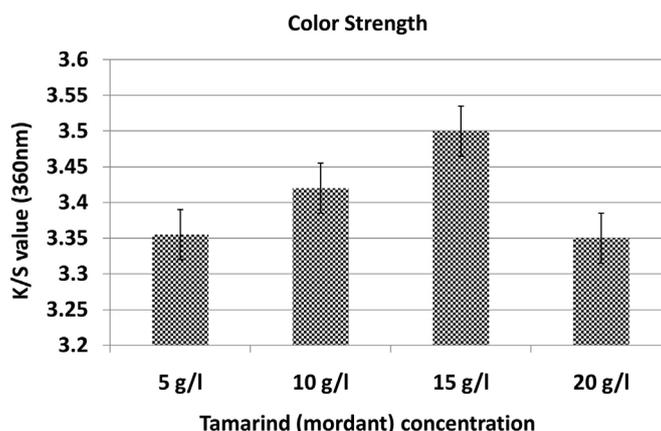


Figure 3. Tamarind (mordant) concentration variation on K/S values of the dyed fabric.

3.2. Effect of Temperature Variation on K/S Values of the Dyed Fabric

Figure 4 shows that, color strength (K/S) value of the sample dyed with 80°C is high and it is decreasing at the temperature of 60°C, 40°C, room temperature as well as 100°C. At 60°C and 100°C temperature, K/S value is moderate. At room temperature (25°C) and 40°C temperature, K/S value is low.

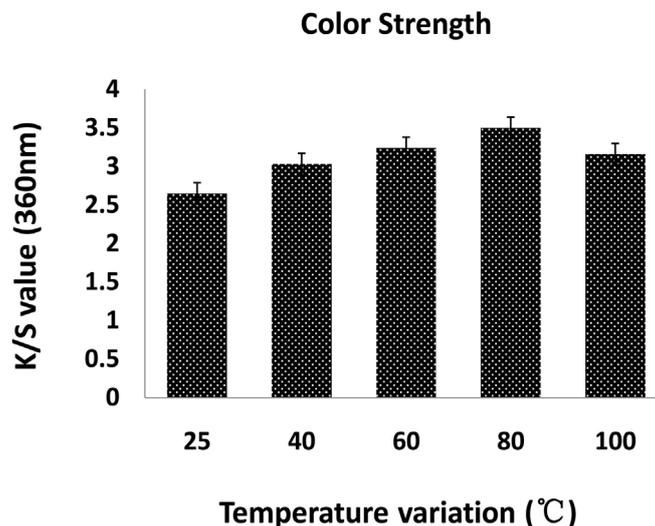


Figure 4. Temperature variation on K/S values of the dyed fabric.

3.3. Effect of Time Variation on K/S Values of the Dyed Fabric

Figure 5 illustrates that, K/S value of 60 min sample is high, for 80 min and 90 min sample is moderate; for 15 min and 40 min sample is low. Lower values of the samples shows that dye has lower substantivity towards the fabrics.

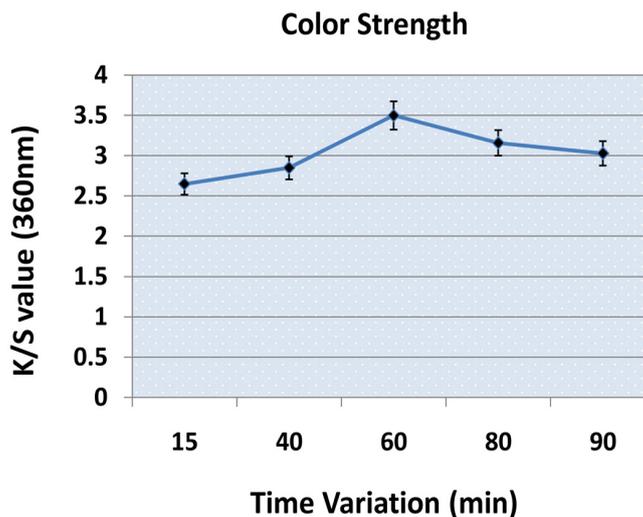


Figure 5. Illustration of time variation on K/S values of the dyed fabric.

3.4. Effect of Tamarind (Mordant) Concentration Variation on Brightness, Chromacity and Hue

Figure 6 illustrates that, concentration variation of alum has no significant effect on brightness, chromacity and hue. But brightness result was excellent with 10 gm/l Tamarind (mordant) and with others it was good. And chromacity was moderate for every concentration. With 25 gm/l tamarind (mordant) hue effect was good than that of other mordants.

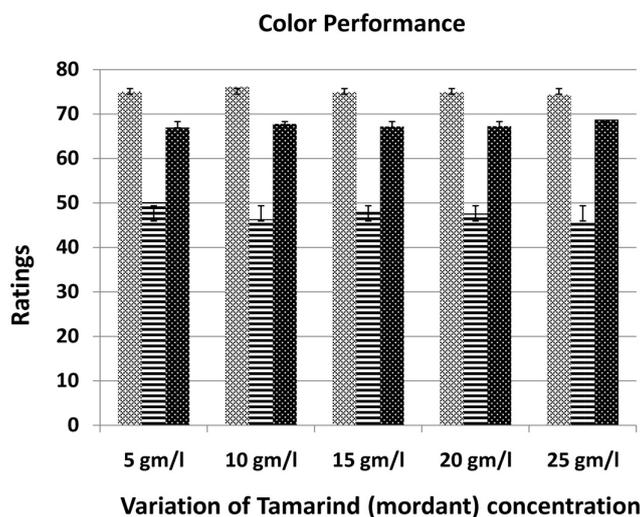


Figure 6. Tamarind (mordant) concentration variation on brightness, chromacity and hue.

3.5. Effect of Temperature Variation on Brightness, Chroma and Hue

Figure 7 illustrates that, temperature variation has no significant effect on brightness, chromacity and hue. But brightness result was excellent at room temperature and with others it was moderate to excellent. Chromacity was good to excellent for every temperature. With 100°C temperature hue effect was good than that of other temperature.

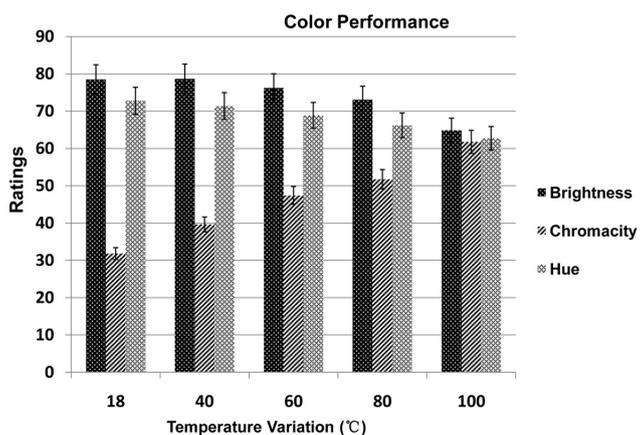


Figure 7. Variation of temperature on brightness, chromacity and hue.

3.6. Effect of Time Variation on Brightness, Chromacity and Hue

Figure 8 illustrates that, time variation has no significant effect on brightness, chromacity and hue. But brightness result was excellent at 15 min. and with others it was moderate to excellent and chromacity was good to excellent for every time. With 60 min hue effect was good than that of other temperature.

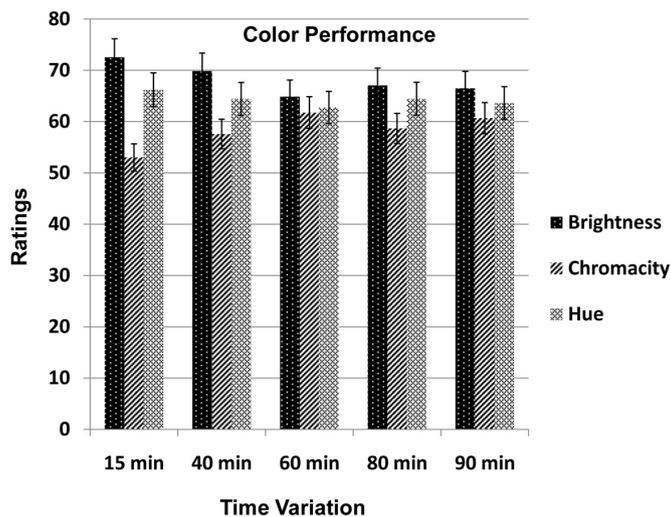


Figure 8. Effect of time variation on brightness, chromacity and hue.

Figure 9 shows the images of different samples at different processing time. After mordanting with tamarind seed coat tannin the sample gains some color. The only dyed sample is very bright but its fastness properties are not as good as previously observed. For regaining the brightness, the sample was further treated with copper sulphate but it has got a little change.

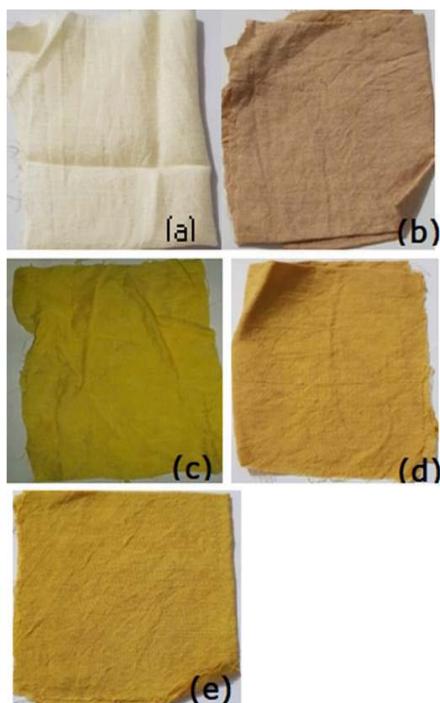


Figure 9. Representation of different dyed samples with different parameters. (a) Raw sample (without mordant); (b) Mordanted sample; (c) Only dyed sample; (d) Mordanted and dyed sample; (e) Mordanted, dyed and CuSO_4 treated sample.

3.7. Effect of Color Fastness to Wash on Change of Dyeing Parameter

Color fastness to wash was observed by both change in color and staining in color grey scale. The result is shown in **Table 1**.

Table 1. Color fastness to wash at various dyeing parameters.

Samples	Change in color	Staining in color					
		Diacetate Cotton	Polyamide	Polyester	Acrylic	Wool	
Only dyed Sample	2 - 3	3	2	2	3	3	2 - 3
Mordanted and dyed Sample	4	4	3	2 - 3	5	5	5
Mordanted, dyed and Copper sulphate treated Sample	4 - 5	4 - 5	3 - 4	3	5	5	5

The above observation implies that, color fastness to wash for only turmeric dyed sample was not good enough (the range between fair to good). Color fastness to wash for mordanted and dyed sample has been improved (it was at the range very good to excellent). And, color fastness to wash for mordanted, dyed and copper sulphate treated sample has been slightly improved than the previous one.

3.8. Effect of Color Fastness to Rubbing on Different Dyeing Parameter

Color fastness to rubbing was done by crockmeter and observed by Grey scale for staining in color. The result is shown in **Table 2**.

Table 2. Color fastness to rubbing on different dyeing parameter.

Samples	Staining in color	
	Dry Rub	Wet Rub
Only dyed Sample	4	3 - 4
Mordanted and dyed Sample	5	4 - 5
Mordanted, dyed and Copper sulphate treated Sample	4 - 5	4 - 5

The above observation implies that, color fastness to rubbing (both in dry rub and wet rub) for “only turmeric dyed sample” was improved in case of “tamarind powder mordanted and dyed sample”. Color fastness to rubbing for “mordanted, dyed and copper sulphate treated sample” has been almost same to “mordanted and dyed sample”.

3.9. Effect of Color Fastness to Perspiration on Different Dyeing Parameter

Color fastness to perspiration was observed by both grey scale for change in color and staining in color. The result is shown in **Table 3**.

Table 3. Color fastness to perspiration on different dyeing parameter.

Samples	Test Medium	Change in color	Staining in color					
			Diacetate	Cotton	Polyamide	Polyester	Acrylic	Wool
Only dyed Sample	Alkaline	3 - 4	4	4	4	4	4	4
	Acidic	3 - 4	4	4	4	4	4	4
Mordanted and dyed Sample	Alkaline	4	5	5	5	5	5	5
	Acidic	4	5	5	5	5	5	5
Mordanted, dyed and Copper sulphate treated Sample	Alkaline	4 - 5	5	5	5	5	5	5
	Acidic	4	5	5	5	5	5	5

The above observation implies that, color fastness to perspiration for only turmeric dyed sample has been improved for mordanted and dyed sample. Color fastness to perspiration for mordanted, dyed and copper sulphate treated sample has been almost the same to mordanted and dyed sample but improved from only turmeric dyed sample.

3.10. Effect of Color Fastness to Water on Different Dyeing Parameter

Color fastness to water was observed by both change in color scale and staining in color scale. The result is shown in **Table 4**.

Table 4. Color fastness to water on change of dyeing parameters.

Samples	Change in color	Staining in color					
		Di acetate	Cotton	Polyamide	Polyester	Acrylic	Wool
Only dyed Sample	2 - 3	3	2 - 3	2 - 3	3	3	2 - 3
Mordanted and dyed Sample	4 - 5	4	4	3 - 4	4 - 5	5	5
Mordanted, dyed and Copper sulphate treated Sample	4 - 5	4 - 5	4	3 - 4	5	5	5

The above observation implies that, color fastness to water for “only turmeric dyed sample” was not good enough (the range between fair to good). Color fastness to water for mordanted and dyed sample has been improved (the range between very good to excellent). Color fastness to water for “mordanted, dyed and copper sulphate treated sample” has been slightly improved than the previous one.

3.11. Effect of Color Strength on Different Dyeing Parameters

Table 5 describes the comparison of color strength value at different dyeing conditions. The only dyed value shows the higher value. Tamarind mordanted plus dyed sample shows 3.5 which is acceptable for making a shade and gives

good fastness property as previously noted.

Table 5. Evaluation of color strength on different dyeing parameters.

Sample	Wavelength (nm)	K/S value
Only Dyed	430	6.4
CuSO ₄ + Tamarind mordanted + Dyed	430	3.4
Tamarind mordanted + Dyed	430	3.5

4. Conclusion

Tamarind seed, as a by-product of tamarind pulp industries, basically is a distinctive underutilized material. The feasibility of tamarind seed coats extract as a natural mordant for dyeing silk fabric with turmeric powder dye via color measurement and color fastness testing was investigated in this study. The effect of mordanting on the color strength and fastness properties was studied in the course of the investigation. This study also investigated the optimal conditions of this dyeing process for getting good results by varying tannin concentration, time and temperature of dyeing. On the basis of the above study, authors got better results at 15 g/l (owf) tannin (tamarind seed coat extracted) treated sample dyeing for 60 min at temperature 80°C. Mordanting with tannin improves overall fastness properties and color strength value. Thus natural dye with tamarind mordanted natural mordant may serve as an eco-friendly alternative to their synthetic counterparts to make a greener life. There is hope that, natural coloring can be customized for rigorous approach functional parameters of synthetic dyestuffs and can be cost effective opportunities for the textile and clothing industry through systematic research.

Suggestions for Future Work

- In this experiment, tamarind seed coat was used to extract tanin, previous work has been carried on using amla fruit to extract tanin. Further works can be carried on using fruit, bark, stem, stock or other parts of different trees to extract tanin and use as mordant. In future, researchers may get more sources for tanin extraction.
- Here, water medium was used for extraction of tanin from tamarind seed coat form, but in future researchers may continue experiment using other media for mordant extraction like alkaline medium etc.
- Turmeric powder used here as sources of natural dye in combination with tamarind seed coat tanin. But, in the future, further experiments may be carried out by using other natural sources of dyes and possible to get better performance.
- To get better color fastness properties, the fabric can be treated with slightly acidic citric acid from natural sources like orange etc. As silk is a protein fiber made fabric, it may improve the color fastness properties especially wash fastness.

These are some future work suggestions. But it is true that research is a never ending process. So, there are a lot more chances to modify and pursue advanced research work from here. We anticipate that our initiative will be advanced in the future and a lot more works will go on from our initiative.

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Conflicts of Interest

The authors have declared no conflict of interest.

Compliance with Ethics Requirements

This article does not contain any studies with human or animal subjects performed by any of the authors.

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