

ORIGINAL ARTICLE

Cleaner isolation and application of sustainable new novel source of natural dye from tallow laureal (*Litsea glutinosa*) for silk dyeing

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Abstract

The utilization of waste plant residues in useful work particularly as the source of green dyes in textiles is now a days welcoming by global community. In this study, brown bollygum chips (*Litsea glutinosa*) called tallow laurel has been explored for silk dyeing using ecofriendly approaches. Extraction has been done in suitable medium and utilized onto fabric before and after microwave (MW) treatment up to 10 min. Response surface methodology was employed to observe the significant of selected dyeing parameters at which shade development with improved colorfastness was observed. It was found that 2 min radiation to both acidic extract of tallow laurel and silk fabric is the useful condition to get colorfast shade when employed before and after mordanting with iron salt and tannic acid solution as eco-chemical agent, whereas with walnut bark and pine nut hulls extract as eco bio agents. The highest color strength value of 4.58 was observed using tannic acid as postchemical mordant for silk dyeing. The standard methods for fastness as per ISO to light, washing, and rubbing reveal that using selected shades made under ecofriendly cost time and energy effective conditions, stable colorfast hues were rated good with the value of 4/5. Therefore, it is recommended that MW treatment in addition with statistical approach i.e., central composite

design used for exploring new dye yielding plant, then using eco-mordanting technique will help in getting promising colorfast shades.

KEYWORDS

bio-mordant, microwave, mordanting, silk fabric, sustainability

1 | INTRODUCTION

The surge of green products is the demand of current era. This revival of green ecofriendly products is due to the spread awareness of toxic behavior of chemicals used in the formation and application of synthetic products. Their effluent when discharged into the land and water ecosystem cause global heat, spread of various diseases and lead to destruction of global beauty.¹ In the revival of green products, natural dyes are gaining widespread attraction towards the people. Natural dyes are obtained by extracting colorants from various plant components, including leaves, roots, stems, flowers, and fruits.² For instance, indigo dye is acquired from the leaves of indigo plant, cochineal dye is derived from the dried bodies of specific insects,³ madder dye is extracted from the roots of madder plant,⁴ and turmeric dye is obtained from the rhizomes of the turmeric plant.⁵ Since ancient times, these dyes have been used for dyeing fabrics such as wool, silk, and cotton. These dyes have been extensively used for coloring textiles, artworks, and other materials.⁶

The process of obtaining natural dyes often involves extraction and purification techniques to isolate the desired colorants from the source material. Conventional or traditional methodologies encompass a variety of techniques such as soaking, stirring, room temperature heating, boiling, maceration, soxhlet method, and solvent-based methods.⁷ However, these conventional extraction approaches comprise certain limitations. The extraction processes are characterized by a long duration, in conjunction with significant consumption of energy (fuel), water, and chemical agents.⁸ Consequently, these methods are economically challenging, environmentally unsustainable, and exhibit inadequate efficiency, demanding a change towards more efficient and cost-effective alternatives.⁹ Now modern approaches have been taken to make process greener and more cost-effective as well as to improve process yield from natural sources for their potential behavior towards ecofriendly products.¹⁰ Among such methods, microwave (MW) treatment is easily available green technology for the valorization of waste plant material for textiles and other allied fields.¹¹ Unlike, traditional surface heating methods, MW heating operates through volume-based interaction. This mechanism is based on

the activation of polar molecules within the treated medium, a phenomenon known as polarization, which weakens the molecular bonds.¹² This heat not only permeates the dye material, facilitates the efficient transfer, and causes dissolution of dye components in the solvent that results in the high extraction yield at an accelerated rate. Additionally, the energy distribution is uniform and consistent, setting it apart from conventional techniques.¹³

Various sources have already been used for the extraction of natural dyes and their application on the coloration of textile materials.^{14,15} For examples, Chowdhury et al.¹⁶ extracted natural dyes from neem leaves for the coloration of cotton fabric using bio mordants. Akram et al.¹⁷ explored the color extraction from *Syzyguim cumini* leaf powder for the dyeing of organic cotton fabric by ultrasonication. Liman et al.¹⁸ reported sustainable cotton fabric dyeing using the biowaste from rind of watermelon and seed kernel of mango. In their another study, rind of watermelon and floral stem of banana as source of polyphenols was used for the coloration and UV-protective functionalization on cotton fabric.¹⁹ Islam et al.²⁰ modified the surface structure of cellulosic fibers and then applied natural dyes extracted from floral stem of banana for dyeing and functionalizing of cellulose. In another research by Islam et al.²¹ showed the cotton fabric coloration using biowaste from seed kernel of mango. However, till date, there has been no research, which explores the natural dyes extracted from tallow laureal (*Litsea glutinosa*) for silk dyeing using MW treatment.

L. glutinosa, also well known as Maida Lakdi or Tallow (Figure 1A), is typically found in tropical and subtropical regions, and often grows in lowland rainforests, riverbanks, and marshy areas.²² It is well-adapted to wet and humid conditions. The tallow plant serves as a valuable component of various ecosystems. It contributes to biodiversity by providing habitat and food sources for wildlife.²³ Its bark extract contains varieties of compounds (Figure 1B), due to which its extract has antioxidant, anti-inflammatory and anti-pyretic properties.²⁴ In traditional medicine systems, its extract is used to cure infusion, decoction, diarrhea, and inflammation. It is also used to cure asthma, arthritis, diabetes, edema, and so forth.²⁵ There are many phytochemicals, however,

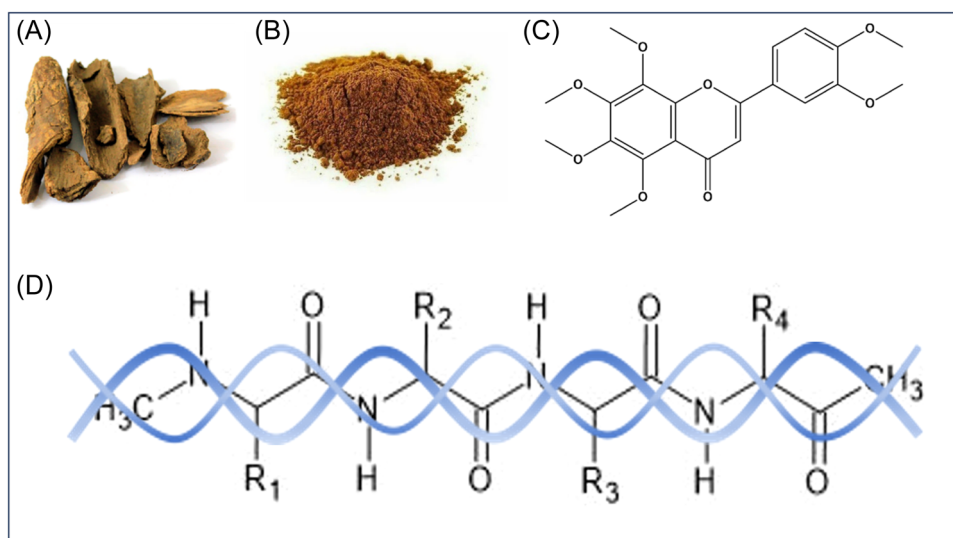


FIGURE 1 (A) Maida lakdi chips, (B) tallow powder, (C) flavonoids, and (D) silk functional unit.

flavonoids (Figure 1C) have potential to impact yellowish brown shade onto fabric such as silk, cotton, and so forth. In the domain of the textile industry, cotton fabric is much more suitable for the globe.²⁶ The structural base of cotton is constituted by a polymer known as cellulose, derived from monomeric glucose units.²⁷ Its terminal –OH group is used to bind with dye and other materials called mordants. Similarly silk fabric has fibroin that contains amide groups (Figure 1D) used for binding with dye and mordants. The aim of the current study is to valorize the waste plant bark (*L. glutinosa*) for silk dyeing (Figure 1D). Additionally, statistical modeling which is response surface methodology was used to make the process more cost and energy effective. Another aim was to introduce plant waste extracts as a source of bio-mordants for the improvement of the color strength and colorfastness properties in the dyed silk fabric.

2 | MATERIALS AND METHODS

2.1 | Collection of material

The chips of Maida Lakdi, called Tallow laurel (*L. glutinosa*), for dye extraction, shells of walnut fruit (*Juglans regia*), pine nut husk (*Pinus gerardiana*), and dried peels of orange fruit (*Citrus X sinensis*) have been purchased, pulverized up to 20 mesh size and stored. Pretreated silk fabric (40 g/m²) was purchased from textile store in Faisalabad, Pakistan. Commercially available salts of aluminum (Al₂(SO₄)₃), iron (FeSO₄), and tannic acid (TA) (C₇₆H₅₂O₄₆) were also purchased for shade developing process from the Pakistan Chemical Stores, Faisalabad, Pakistan.

2.2 | Isolation process

In the current study to extract the coloring material from the plant, one type of radiation mode was employed which was MW radiations. The aqueous, and acidic media were used to extract the colorant. The preparation of the aqueous extract involved boiling 4 g of dried tallow powder with 100 mL of distilled water for 60 min, maintaining a solvent to powder ratio of 25:1. In another extract, the preparation of the acidic extract involved boiling 4 g of dye powder with 100 mL of acidic medium for 60 min, while maintaining a solvent to powder ratio of 25:1. Following the boiling process, the extract was filtered and utilized for subsequent experiments. For preparation of acidic medium, 2% HCl solution (v/v%) was selected to see the comparative effect on extraction yield in value of tonal expressions and color strength (K/S) onto fabric.

2.3 | Mordanting

In this research, experiments using two different types of mordanting such as pre- and postmordanting have been performed. There are two types of mordants that were used for mordanting called as chemical and bio-mordants. For premordanting procedure, 0.5%–2.5% of mordant solution was employed to mordant the silk fabric at the mordant to fabric ratio of 25:1. The mordanted fabric was then subjected to dye with tallow powder extract using selected conditions. For the postmordanting process, the dried tallow powder extract was used to dye silk fabric at selected conditions and then mordanted with 0.5%–2.5% of mordant solution at

80°C for 45 min. The same process of aluminum mordanting was done before and after dyeing of the silk fabric. Similarly, iron salt and TA solution were prepared and utilized before and after dyeing of silk at given conditions. A similar process was repeated with pinenut husk powder and with orange peel powder, whose 0.5–2.5 g were utilized for boiling with 100 mL of water to get bio-extracts. Then, 25 mL of extracts from each bio-source powder were utilized before and after dyeing of silk fabric at 80°C for 45 min. The schematic representation of the dye extractions and dyeing of silk fabric using tallow powder is shown in Figure 2.

2.4 | Analysis of fabric and dye

The surface morphology of the silk fabric was observed through scanning the images of fiber by scanning electron microscope (SEM; Zeiss) at the voltage of 5 KV using (WD 29 mm PC 42) magnification power 1000×, with image size 10 μm. Before and after radiation, the scanned images were taken and analyzed. Similarly, for chemical changes, the functional peaks of silk binding sites such as, amido linkages were assessed through Fourier-Transformed Infrared (FTIR) Spectroscopy (Perkin Elmer).²⁸

2.5 | Analysis of coloring properties

The color variables were measured for dyed fabrics through Spectro-flash (SF-600; Data color) using Kubelka–Munk Equation (1) at D65 light and 10° observer.²⁹ The shade expression terms have been assessed using CMC equation and shade depth before and after treatment were analyzed.

$$K/S = (1 - R)^2/2R \quad (1)$$

Here, K = Absorption co-efficient; S = Scattering co-efficient; R = Decimal fraction of reflectance.

2.6 | Analysis of shade stability properties

For observing shade permanency, ISO standards for colorfastness to light, washing and rubbing were utilized. To assess colorfastness to light, the dried dyed fabric was physically divided into two parts using a lead pencil. One half of the fabric was shielded from light exposure, while the other half was left exposed to light for approximately 48 h. A fado-meter Pak -made-Xe source) was employed to compare the exposed and unexposed fabrics and determine their respective colorfastness. The evaluation of colorfastness to light was conducted following the international standard of ISO-105-B02.³⁰ For wash fastness, a small piece of dyed fabric was placed between two small pieces of undyed silk fabrics using common pins to hold them together. Subsequently, 0.5 g of neutral soap and 0.5 g of Na₂CO₃ were dissolved in 100 mL of water, and the mixture was heated for 10 min. From this solution, 30 mL was transferred into a beaker, and the prepared fabric sandwich was added to it, followed by heating for 20 min. After removing the fabric from the soap solution, it was thoroughly rinsed with both hot and cold water and allowed to air-dry at room temperature. The machine used for the colorfastness to wash was Rota wash (James Heal GyroWash) and the standard was ISO-105-C03.³¹ Colorfastness to rubbing of the dyed fabrics was examined using a crock meter (Pak made). The dyed silk fabric was positioned at the base of the crock meter, while the undyed silk fabric was placed at the holder of the crock meter, enabling the observation of any color change during the rubbing

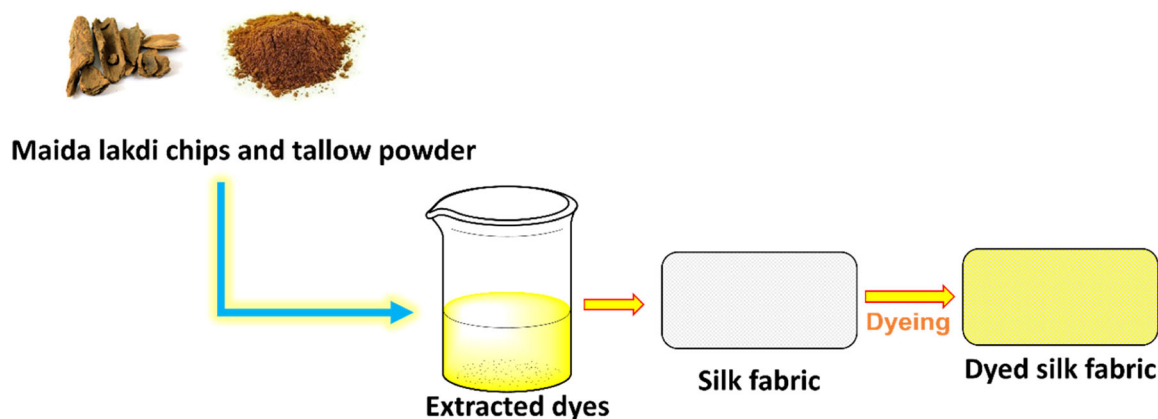


FIGURE 2 Schematic presentation of silk dyeing using natural dye extracted from tallow powder.

process. To assess rubbing fastness, 12 turns of the crock meter were completed for both wet and dry rubbing independently. In accordance with ISO standards (ISO 105 X-12), the color change and color stain values were then evaluated.³²

3 | RESULTS AND DISCUSSION

3.1 | SELECTION OF EXTRACTION MEDIUM AND IRRADIATION LEVEL

Since last decades, the MW rays are being utilized in the extraction of the natural dyes. These rays are gaining popularity due to their uniform action on the extraction system also.³³ These rays effectively penetrate and interact with the system, resulting in efficient kinetics during the isolation process. When MWs come into contact with plant powder, these rays weaken the cell wall and facilitate the penetration of functional molecules (dye) into the solvent through solid-liquid interaction. This process consumes less solvent, time, and energy³⁴ and after application of dye, high yield is

observed. Utilizing an acidic solvent, the extraction of colorant from tallow powder after exposure to radiation for 2 min, has resulted in a significant dye yield ($K/S = 5.28$). On changing to an aqueous medium, irradiating tallow powder extract up to 4 min, has produced a high color intensity ($K/S = 1.86$) on fabric (Figure 3A,B). Comparatively, irradiating tallow powder extract and silk fabric, using an acidic medium, has demonstrated outstanding results ($K/S = 5.28$). Similarly, using an acidic medium, the color characteristics of dyed fabric exhibit distinct changes before and after irradiation. Before irradiation, the dyed fabric appears brighter and has a reddish-yellow hue. However, after irradiation, the fabric becomes darker and exhibits a more intense reddish-yellow hue. The aqueous extract used for dyeing produces a brighter shade with a reddish-yellow hue (Supporting Information: Table S1).

The irradiation of the fabric is another key aspect to consider. Our previous investigations shown that fabric irradiation modifies the surface by formation of scaling.³⁵ This scaled surface has the ability to absorb colorant molecules during dyeing to a significant extent. The scaling was confirmed by analyzing the silk fiber surfaces

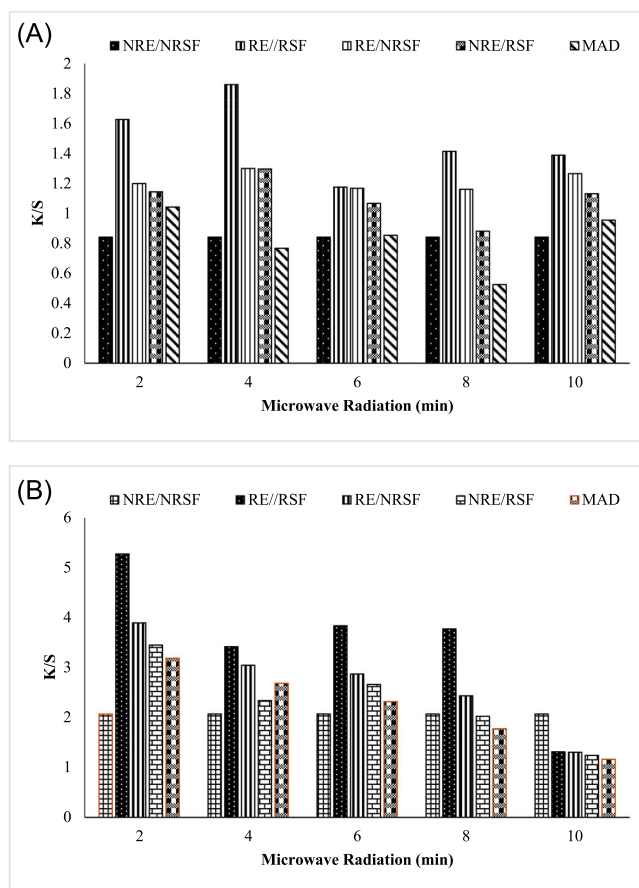


FIGURE 3 The impact of microwave radiation on silk dyeing utilizing the (A) aqueous, and (B) acidic extract of tallow powder.

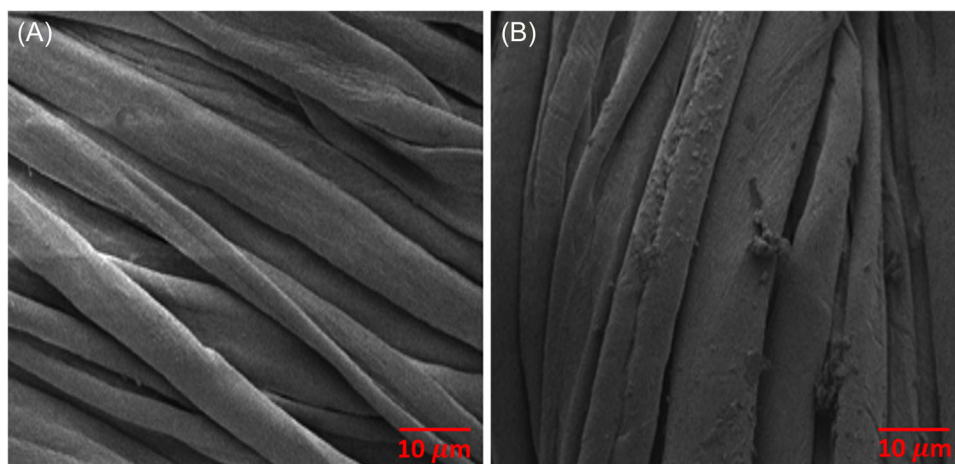


FIGURE 4 Scanning electron microscope images of (A) unirradiated and (B) microwave irradiated of silk fabric.

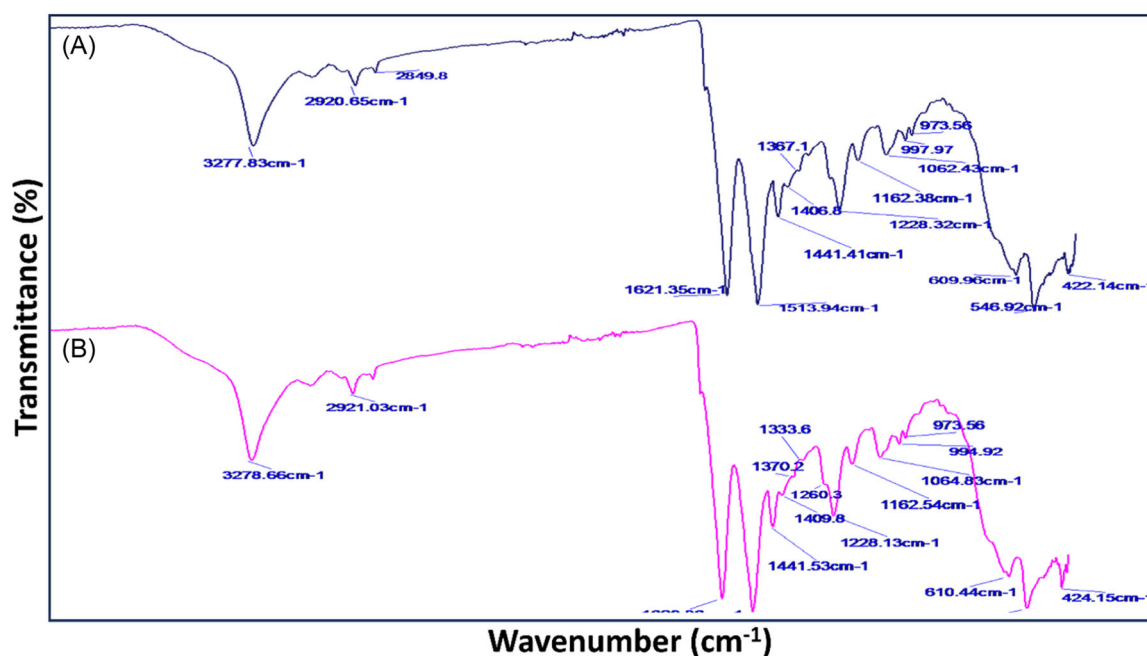


FIGURE 5 Fourier-Transformed Infrared spectra of the (A) control and (B) microwave irradiated silk fabric.

using SEM images (Figure 4). Moreover, the structural change of the silk fiber was examined using FTIR spectroscopy. The ATR-FTIR spectra of the fibers before and after irradiation revealed no chemical changes, as the positions of specific functional peaks representing amido groups remained unchanged (Figure 5). Our previous studies have also confirmed that MW rays does not cause any chemical change.³⁶ Hence, it was proved that MW radiation alters the fiber surface physically without affecting its chemistry, which is a positive indication for its application in the natural dyeing process.

3.2 | Statistics analysis for selection of dyeing parameters

The statistical analysis in Supporting Information: Table S2 and Table 1 has shown that the dyeing of silk with tallow powder extract under optimum conditions yields significant results. The model utilized for analyzing the dyeing to silk is suitable and linear. Several factors, including pH (0.000), dyeing time (0.006), and temperature (0.012), have played the significant role in the dyeing process. The dual interaction between pH and temperature (0.005) is

TABLE 1 Analysis of variance using response surface regression K/S versus salt, time, pH, and temperature for silk fabric.

Source	Df	Adj SS	Adj MS	F-value	p Value
Model	12	6.16013	0.51334	27.18	0.000
Linear	4	3.63601	0.90900	48.14	0.000
Salt	1	0.00042	0.00042	0.02	0.883
pH	1	3.20084	3.20084	169.50	0.000
Time	1	0.19337	0.19337	10.24	0.006
Temperature	1	0.15138	0.15138	8.02	0.012
Square	2	2.46234	1.23117	65.20	0.000
Salt × salt	–	–	–	–	–
pH × pH	1	2.43439	2.43439	128.91	0.000
Time × time	–	–	–	–	–
Temp × emp	1	0.03322	0.03322	1.76	0.203
2-way interaction	6	0.32575	0.05429	2.88	0.043
Salt × pH	1	0.02408	0.02408	1.28	0.275
Salt × time	1	0.01339	0.01339	0.71	0.412
Salt × temperature	1	0.00169	0.00169	0.00169	0.768
pH × time	1	0.14877	0.14877	7.88	0.013
pH × temperature	1	0.19600	0.19600	10.38	0.005
Time × time	0.00212	0.00212	0.00212	0.11	0.742
Error	16	0.30214	0.01888	–	–
Lack of fit	8	0.10620	0.01327	0.54	0.798
Pure Error	8	0.19595	0.02449	–	–
Total	28	6.46227	–	–	–

Model summary		
S	R-sg	R-sg (adj)
0.137419	92.32%	91.82%

highly significant, as well as the interaction between pH and both time (0.013) is also substantial. Optimal temperature is necessary to achieve vibrant colors by improving the kinetics of the dye bath. Maintaining an appropriate dyeing time also helps in preventing dye molecule sorption and this sound fabric–dye interaction, resulted in excellent K/S values. The use of salt aims to enhance color depth and fastness by promoting short-range forces between the fabric and dye under specific conditions.³⁷ Additionally, maintaining an optimum pH is significant for establishing H-bonding between the dye and fabric, leading to enhanced shade development and fastness properties.³⁸

3.3 | Shade development procedure

Mordanting with chemical and bio-moieties for the natural dyeing of silk is necessary to develop permanent shades to fabrics.³⁹ The process of mordanting, whether applied before or after dyeing, serves to enhance the firmness and stability of the dyeing process through the formation of coordinate covalent bonds.⁴⁰ Moreover, mordanting plays a crucial role in the formation of new colors and shades in natural dyeing, as well as in improving the quality of textiles and the rating of colorfastness. The result of mordanting varies depending on the dyeing method, the nature of the colorant and

fiber, resulting in a wide range of tint variations with enhanced characteristics.⁴¹ Both chemical and bio mordants offer numerous shades when applied during pre- and posttreatment of fabrics. Certain chemical mordants, such as Al, and Fe-salts as well as TA, have been found for their environmentally friendly and sustainable characteristics. The application of bio-mordanting has been emerged as one of the more eco-friendly and sustainable approach in natural dyeing of fabric. This process not only enhances color coordination of dye with fabrics but also helps in the development of new shades, particularly in fabrics with antibacterial properties.⁴²

In this study, our research revealed that the application of 1.5% Al-salt before dyeing (prechemical mordant), has resulted in the strong and firm shade on silk fabric. On applying, 1.5% Al mordant after dyeing (postchemical mordant), using optimized extraction conditions, exhibited bright reddish yellow shade. Using 1% Fe as a

prechemical mordant, followed by dyeing under optimized extraction conditions, leads to a fabric shade with less red and more yellow hues, along with brighter tints ($L^* = 72.05$, $a^* = 6.02$, $b^* = 19.27$) (Figure 6). On the other hand, applying (1%) Fe as a after dyeing (postchemical mordant) onto the silk fabric using optimized extraction conditions results in a shade with less red and more yellow hue, along with brighter shades ($L^* = 56.18$, $a^* = 4.78$, $b^* = 16.01$). However, the fabric dyed with the optimal conditions and postmordanting (Table 2) exhibits a brighter shade with a redder and yellower appearance ($L^* = 56.18$, $a^* = 4.78$, $b^* = 16.01$). When iron is used in the Fe^{3+} (ferric) form, it tends to produce darker shades due to stronger interactions with dye molecules. Using iron in the Fe^{2+} (ferrous) form results in brighter shades because of the relatively weaker interactions with the dyes.⁴³ The results presented in Figure 6 revealed that the utilization of (1%) TA before dyeing (prechemical mordant) with an irradiated acidic extract for a duration of 2 min has given good results. Additionally, the application of (1.5%) TA after dyeing (postchemical mordant), on silk fabric with the irradiated acidic extract for 2 min has also given good results. The obtained shade showed that the predyeing application of TA results in hues that are less red and more yellow, with brighter tints ($L^* = 73.67$; $a^* = 5.71$; $b^* = 20.73$). On the other hand, the postdyeing application of TA yields hues that are less red and yellow, with brighter shades ($L^* = 53.15$; $a^* = 5.67$; $b^* = 18.51$).

Bio-mordanting has emerged as an innovative approach employed to enhance both the durability and colorfastness characteristics of dyed fabrics. The efficacy of bio mordant resides in their ability to establish chemical bonds with dye compounds and textiles such as silk through the interaction of $-\text{OH}$ functional group.⁴⁴ Moreover, the phenomenon of conjugation

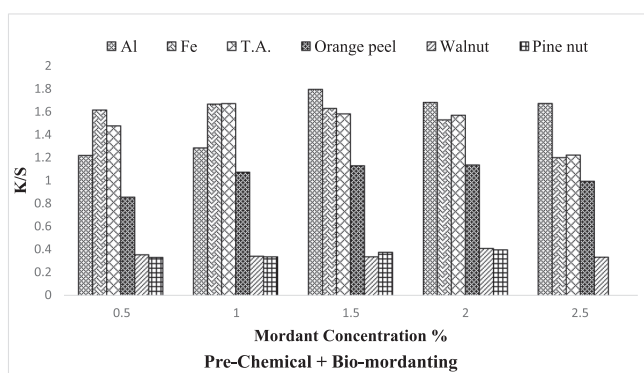


FIGURE 6 Color strength value of the dyed silk fabric using prechemical and bio mordanting with Al-salt, Fe-salt, tannic acid solution, orange peels, walnut, pine-nut husk extracts at selected conditions.

TABLE 2 The color coordinates of silk fabric, subjected to microwave treatment and dyed with chemical mordants, both before and after the application of an irradiated extract.

Silk fabric							
Chemical mordanting				Bio mordanting			
Mordant concentration %	L^*	a^*	b^*	Mordant Concentration %	L^*	a^*	b^*
Al 1.5% pre	69.98	8.07	21.48	Orange peel 2%pre	77.79	3.14	16.51
Al 1.5% post	69.76	7.73	20.55	Orange peel 2% post	67.53	7.55	18.83
Fe 1% pre	72.05	6.02	19.27	Walnut 2% pre	84.4	1.8	7.58
Fe 1% post	56.18	4.78	16.01	Walnut 2% post	79.81	3.01	10.75
T.A. 1% pre	73.67	5.71	20.73	Pine-nut 2% pre	84.57	1.64	7.03
T.A. 1.5% post	53.15	5.67	18.51	Pine-nut 1.5% post	79.66	3.11	10.82

plays a vital role in effective changes in the dyeing characteristic when bio mordants are mixed with dyes, ultimately leading to the appearance of novel colorfast hues.⁴⁵ The experimental findings displayed in Figure 7 indicate that application of (2%) orange peel before dyeing (pre-bio mordant), under optimal conditions, yields favorable results. Table 2 demonstrate that premordanted fabrics exhibit a less reddish ($a^* = 3.14$) hue, brighter shade ($L^* = 77.79$) with yellowish tone ($b^* = 16.51$) shades. On the other hand, fabrics dyed

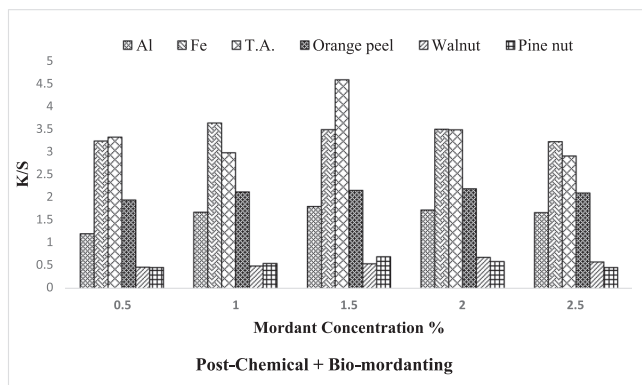


FIGURE 7 Color strength value of the dyed silk fabric using postchemical and bio mordanting with Al-salt, Fe-salt, tannic acid solution, orange peels, walnut, pine-nut husk extracts at selected conditions.

before postmordanting display a more reddish and yellowish hue, and dark shade ($L^* = 67.539$; $a^* = 7.55$; $b^* = 18.83$). However, overall, the application of 2% orange peel as a postmordanting agent result in fabrics with reddish and yellowish hue, of dark shade ($L^* = 67.53$; $a^* = 7.55$; $b^* = 18.83$). Figure 6 revealed that (2%) of walnut as (pre-bio mordant) fabric dyed after mordanting at optimal extraction conditions given good results. Then application of (2%) of walnut after dyeing (as post-bio mordant) onto fabric at optimal extraction conditions given good tone. Table 2 revealed that premordanted fabrics are less-redder ($a^* = 1.8$), less yellower ($b^* = 7.58$) and more-brighter ($L^* = 84.4$) in tint. Whereas the fabric dyed before postmordanting are also much redder and much yellower in hue and brighter in tint ($L^* = 79.81$; $a^* = 3.01$; $b^* = 10.75$). But overall Walnut as postmordanting has given the more redder and the much yellower hues with the brighter tone ($L^* = 79.81$; $a^* = 3.01$; $b^* = 10.75$). Figure 7 displayed that (2%) of pinenut before dyeing using acidic extract at optimal conditions given high color strength and (1.5%) of pinenut after dyeing applied onto fabric at optimal conditions given good color strength. Table 2 showed that premordanted fabrics are brighter, reddish and yellowish tone ($L^* = 84.57$; $a^* = 1.64$; $b^* = 7.03$). However, postmordanted fabrics are also much brighter in shade, the more redder and the more yellower in tint ($L^* = 79.66$; $a^* = 3.11$; $b^* = 10.82$). (Thus, overall the

TABLE 3 Impact of prechemical + bio-mordanting on color strength of silk fabric using tallow plant.

Mordant concentration %	K/S values of prechemical + bio-mordanting					
	Al	Fe	TA	Orange peel	Walnut	Pine-nut
0.5	1.22	1.61	1.48	0.86	0.35	0.33
1	1.29	1.67	1.67	1.07	0.34	0.33
1.5	1.80	1.62	1.58	1.13	0.34	0.38
2	1.68	1.52	1.57	1.13	0.41	0.40
2.5	1.67	1.20	1.22	0.99	0.33	0.32

TABLE 4 Impact of postchemical + bio-mordanting on color strength of silk fabric using tallow plant.

Mordant concentration %	K/S values of post-chemical + bio-mordanting					
	Al	Fe	TA	Orange peel	Walnut	Pine-nut
0.5	1.20	3.24	3.32	1.94	0.47	0.46
1	1.67	3.63	2.98	2.12	0.50	0.55
1.5	1.80	3.49	4.58	2.15	0.54	0.70
2	1.72	3.50	3.48	2.19	0.69	0.59
2.5	1.66	3.22	2.91	2.09	0.58	0.46

results presented in Table 3 and Table 4 shown that TA was more effective chemical mordant and orange peel was the more effective biomordant.

3.4 | Fastness properties

The application of bio-mordants and chemical mordants on silk fabrics enhances the fastness properties of colorants, resulting in excellent resistance to fading caused by wash, light, and crocking.⁴⁶ Bio-mordants, with their functional potent molecules, form strong bonds with colorants and fabric, while chemical mordants create firm chemical bonds through metal dye complex formation. The presence of benzenoid rings, conjugation systems, and abundant –OH groups contribute to the excellent hindrance towards color fading.⁴⁷ Overall, selected bio-mordanting and chemical mordanting has demonstrated good fastness rating on using the acid solubilized extract from tallow plants for dyeing. According to the color fastness test results in Table 5, the pre- and postchemical and bio mordanted dyed silk fabric has shown the ratings of 4/5 for light fastness, 4/5 for wash fastness, and 4/5 for rubbing fastness. Therefore, it can be said that the silk fabric dyed using tallow powder have good fastness properties and can be used as source of dye for other fabrics also.

TABLE 5 Color fastness ratings of the chemical and bio mordanted dyed silk fabric using acidic solubilized extract of tallow powder.

Silk fabric				
Mordant concentration %	LF	WF	RF	
			DRF	WRF
Al 1.5% pre	4/5	4/5	4/5	4/5
Al 1.5% post	4/5	4/5	4/5	4/5
Fe 1% pre	4/5	4/5	4/5	4/5
Fe 1% post	4/5	4/5	4/5	4/5
T.A. 1% pre	4/5	4/5	4/5	4/5
T.A 1.5% post	4/5	4/5	4/5	4/5
Orange peel 2% pre	4/5	4/5	4/5	4/5
Orange peel 2% post	4/5	4/5	4/5	4/5
Walnut 2% pre	4/5	4/5	4/5	4/5
Walnut 2% post	4/5	4/5	4/5	4/5
Pine-nut 2% pre	4/5	4/5	4/5	4/5
Pine-nut 1.5% post	4/5	4/5	4/5	4/5

Abbreviations: DRF, dry rubbing fastness; LF, lightfastness; RF, rubbing fastness; WF, washing fastness; WRF, washing rubbing fastness.

4 | CONCLUSION

The world is striving for inclusion of sustainable technologies, green products, and pollution free processing in all walks of life. In field of textiles, MW treatment coupled with statistical methods has been appraised to make dyeing process cost, energy and time effective. For natural dyes, their role has been found much more appreciable as under reduced level of coloration and surface tuning of fabrics have given stable shades. Additionally, the eco-mordanting agents have given new shades with good fastness properties with acceptable ratings. For future aspects, such tools should be used to explore new dye yielding plant wastes into useful coloration purposes. The new bio-sources as bio-mordants should be used to explore new dye yielding plant wastes to get colorfast shades. In this way not only given bi-active dyed products will be introduced beneficial for the global community but also less polluted or pollution free waste will be recycled for other applied fields such as medicines, indicators, cosmetics, and so forth.

AUTHORS CONTRIBUTIONS

Fazal-ur Rehman: Formal analysis; software. **Muhammad Abdul Qayyum:** Formal analysis; writing—review and editing. **Kinza Zainab:** Conceptualization; methodology. **Shahid Adeel:** Resources; writing—review and editing; supervision; project administration. **Noman Habib:** Data curation; writing—original draft; methodology. **Rony Mia:** Formal analysis; investigation; data curation; writing—original draft; writing—review and editing. **Muhammad Imran:** Funding acquisition; writing—review and editing. **Sidra Nasir:** Writing—review and editing.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

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Additional supporting information can be found online in the Supporting Information section at the end of this article.

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