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Dyeing ability of *C. longa* L. and *T. stans* (L.) Juss. Ex Kunth on unmordanted and mordanted silk and cotton fabrics

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Abstract: The work was on the extraction of both the *C. longa* rhizomes and the petals of *T. stans* using four different solvents (ethanol, ethyl acetate, water, and *n*-hexane). The dyeing potential of the *C. longa* and *T. stans* extracts was evaluated on cotton and silk fabrics without or with mordants using potash alum, phosphomolybdic acid, ferrous sulphate, and tartaric acid at varied temperatures and tested for colour fastness properties (wash and light fastness). The pH and absorbance of the dye bath before and after dyeing were studied. However, cotton, which is cellulosic, was better dyed than silk, which is proteinous, which showed a better choice for fabrics dyeing at 80 °C; hence, it had a good colour efficiency. Ferrous sulphate exhibited complexes in the octahedral configuration of the coordination six with CH_2O- of cotton and NH_3^+ and COO^- of silk fabric. In addition, it was also observed that the higher the dyeing temperature, the greater the dyeing intensity. The spectroscopic characterisation of the extracts was determined with the help of UV-Vis and FTIR. The UV-Vis and FTIR spectral analyses revealed the chromophore, auxochrome groups, and functional groups, respectively, within the extracts. Curcumin and rutin were identified as being responsible for the dyeing of the fabric.

Keywords: *C. longa*, *T. stans*, proteinous, cellulosic, mordant

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1. Introduction

Plants play a very crucial role in the textile industry; they have been used to colour textile goods over the years. In the form of a paste or solution, these plant colours are applied. Natural and synthetic dyes are the two types of dyes used in the dyeing of textiles. Natural pigments, usually referred to as natural dyes, are mostly made from the roots, stems, leaves, flowers, fruits, or naturally coloured ores of plants. Natural dyes, usually used due to their lack of potential for environmental harm and being biodegradable, have become increasingly popular throughout time as a replacement for synthetic dyes (Dutta et al., 2021; Che & Yang, 2022). Meanwhile, synthetic dyes provide several environmental challenges and health risks (Ardila-Leal et al., 2021; Dutta et al., 2021; Slama et al., 2021). This suggests that natural dyes will benefit all parties involved in the dyeing process. For example, it can be used to impart colours to various substances such as fabric, hair, drugs, leather, paper, plastics, cosmetics, and food materials. It contains a chromophore and an auxochrome group. The chromophore impacts or gives the dye molecule its colour, such as NO, NO_2, N=OH, N=N, C=O, C=C, while the auxochrome group intensifies the colour of the dye and forms chemical bonds with the fabric by attaching the dye to the fibre, *e.g.,* OH, NH_2, SO_3H, COOH, *etc*. Dyeing is usually an exothermic process; the rate at which dye particles will diffuse is faster at higher temperatures than at lower temperatures, where more fluid is absorbed (Aysha et al., 2022). Extraction of dye from samples is done by solvent extraction (aqueous, enzymatic, microwave, solvent, supercritical fluid, ultrasonic alkali, acid, *etc*.) (Patil et al., 2018; Pizzicato et al., 2023; Sk et al., 2021).

Turmeric, also known as *Curcuma longa* (Syn. *Curcuma domestica* Val.), is a very rich but substantive dye capable of directly dyeing cotton without the use of any mordant, but it is very sensitive to light, soap, and alkali, which has reduced its value considerably (Hasan et al., 2017). The main components of the rhizome are the non-volatile curcuminoids and the volatile oil. It is a polyphenol curcumin. *C. longa* has three main components, which are curcumin, demethoxy curcumin, and bis-demethoxy curcumin (Dosoky and Setzer, 2018) (Figure 1), with 60–75%, 15–30% and 3–15%, respectively (Prasad et al., 2021). An average turmeric rhizome contains about 2–9% curcumin. Curcumin is an ***α,β***-unsaturated-***β***-diketone compound containing two substituted aromatic rings linked by a seven-carbon chain. Each aromatic ring has one hydroxyl and one methoxyl group. It exists as keto-enol tautomerism. The diketo tautomer also exists as *cis* and *trans* tautomers. The *cis* isomer is less stable because the phenolic methoxy groups are on the same side of the curcumin backbone, whereas the more stable *trans* has the two attached groups on the opposite side of the curcumin. It has a colour transition that is influenced by the pH of the reaction bath. It exists as ketonic in acidic and neutral mediums with a yellow colour, but enolate forms in alkaline mediums with a reddish brown colour (Khankaew and Panichayupakaranant, 2023). It is a natural dye found in the root of *C. longa*. Solvents have an effect on the configuration of curcumin. Curcumin is usually extracted using solvent extraction methods which include both polar and non-polar solvents such as hexane, acetone, ethanol, ethylacetate, methanol, chloroform, *etc*. The non-polar and moderately polar solvents often stabilise the enol form of the configuration. Curcumin has two strong absorption bands between 350 and 450 nm and 250 and 270 nm, depending on the extracting solvent (Priyadarsini, 2014).

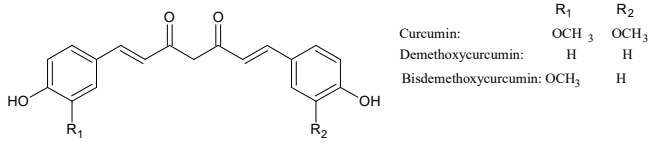


Figure 1. Chemical structures of curcumin derivatives.

Tecoma stans (Syn. *Bignonia stans* L.) (ginger Thomas, yellow trumpet bush, yellow elder, and yellow bells) are fast-growing evergreen plants with 20–30 ft. in height, moderate growth, and yellow flowers. It belongs to the family of Bignoniaceae. These flowers contain *beta*-carotene and zeaxanthin to treat eye disorders (Arunkumar & Yogamoorthi, 2014; Anand & Basavaraju, 2021). Rutin and zeaxanthin have been extracted from ethanolic and ethanol-water mixtures, respectively (Singh et al., 2020) (Figure 2).

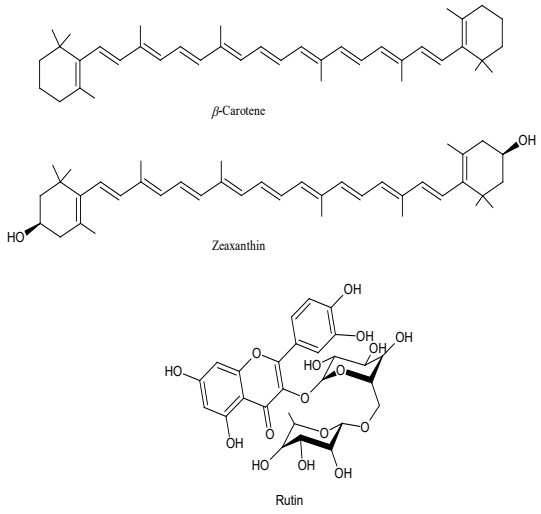


Figure 2. Structures of ***β***-carotene, zeaxanthin, and rutin.

Going through the literature, many studies have been reported on the dyeing ability of *C. longa*, like ultrasound-assisted extraction of curcumin (Patil et al., 2018), and the dyeing properties of turmeric natural colourant on silk and

cotton using $FeSO_4$ and alum as mordant (Mozumder & Majumder, 2016), 1% of $FeSO_4$ and $Al_2(SO_4)_3$ have been used as chemical with 1% of turmeric showing good shades and improved fastness of silk (Adeel et al., 2020). Onal et al. (2020) investigated *C. longa* pre-mordanting, simultaneously-mordanting, and post-mordanting abilities of copper sulfate ($CuSO_4$), ferrous sulphate ($FeSO_4$), and aluminium potassium sulphate ($KAl(SO_4)_2$) as mordants on cotton and wool fabric. Also, lemon juice, *Colocasia esculenta* juice, potash alum, and potassium dichromate were reported as biomordants in dyeing knitted cotton fabric (Hosen et al., 2021) and under some different dyeing conditions (Sarker et al., 2020). In the same vein, *T. stans* has been used to dye cotton fabric using different mordants ($FeSO_4$, $CuSO_4$, $K_2Cr_2O_7$, $FeCl_3$, cow dung, and myrobolon) with different shades of colour (Chandra et al., 2012), and the cold maceration extract of *T. stans* was used in the dyeing of cotton and silk (Rao et al., 2010). But limited research has been documented in relation to the dyeing of *C. longa* and *T. stans* with regard to absorbance in determining the exhaustion of dye using some new mordants and the contribution of hydrogen ions of the dyeing bath. In this work, the dyeing abilities of *C. longa* and *T. stans* were studied and compared using different mordants, such as phosphomolybdic acid, ferrous sulphate, tartaric acid, and aluminium potassium sulphate dodecahydrate, and without mordant. The extracts were used to compare the dyeing properties of cotton and silk.

2. Materials and methods

All the reagents were analytical grade: ethanol, *n*-hexane, ethyl acetate, sodium carbonate, sodium sulphate and aluminium potassium sulphate ($KAl(SO_4)_2{\cdot}12H_2O$), were purchased from Loba Chemie Chemicals, India, non-ionic detergent (So klin multipurpose detergent), ferrous sulphate ($FeSO_4$), tartaric acid ($C_4H_6O_6$), phosphomolybdic acid ($H_3PMo_{12}O_{40}$) were purchased from BDH, England and Sigma- Aldrich, Germany.

2.1. Collection of plant materials

The floral parts of cultivated yellow elder *(T. stans* (L.) Juss. Ex Kunth) were collected from trees at the main gate of the University of Benin, Ugbowo campus, Benin City, Edo State (postal code 300213) with voucher number UBH-T311. The rhizomes of cultivated *C. longa* Linn were obtained from Uselu Market, Benin City, Edo State (postal code 300212) with voucher number UBH-T397. Both samples were collected in February 2022 and identified by Dr. H. N. Akinnibosun, in the Department of Plant Biology and Biotechnology, Faculty of Life Science, University of Benin, Benin City, Nigeria. The fabrics used for this experiment were purchased from a natural cellulosic fibre shop at Uselu Market (cotton and silk). Cotton and silk (20 × 20 cm) were used to test the dyeing abilities of the extracts.

2.2. Preparation of plants for extraction

The petals of *T. stans* were crushed, and the rhizomes of *C. longa* were washed with distilled water to remove all earthy substances and impurities and cut into tiny pieces (about 0.001 m for easy drying). Both plants were spread in shade for 12 days at room temperature at 28-30 °C until there was no trace of moisture. The plant samples were ground mechanically to make them powdered for effective extraction.

2.3. Extraction of dye from plants

Extraction was done using the solvent extraction method. The solvents used were distilled water, ethanol, *n-hexane,* and ethyl acetate. 25 g of each powder (used separately) were put into 250 mL of the four different solvents, respectively (1:10 w/v), making a total of eight (8) solutions prepared from both plants. The solutions were then intermittently shaken on a shaker for 48 h, and the extract solution was then filtered three (3) times using filter paper (Whatmann 12.5 cm, 1001 Qualitative). All the extracted solutions were kept at ambient temperature without exposure to direct sunlight and were used within three days.

2.4. Spectroscopic analysis

The absorption spectra of the dye extracts were measured using UV-Visible spectrophotometer (6715 UV/VIS Spectrophotometer (JENWAY)). The functional group of the extracts was confirmed using a Fourier transformed infrared spectrophotometer (FTIR) (Agilent Technologies), and the wavenumber was recorded.

2.5. Scouring (degumming of fabric)

Pieces of plain-woven cotton and silk fabrics were weighed, and scouring was done by washing them in a solution containing 0.5 g/L sodium carbonate and 2 g/L nonionic detergent (So Klin multipurpose detergent) at 50 °C for 25 min, keeping the material to liquor ratio at 1:40 w/v. This was done to remove impurities like starch and other additives used during weaving so as to increase the colour yield and dye affinity on the fabrics. The scoured fabrics were thoroughly washed with tap water and dried at room temperature. The materials were later soaked in clean water for 30 min prior to mordanting.

2.6. Mordanting

Mordanting was carried out by accurately weighing cotton and silk fabrics, and the same were treated with different mordants (ferrous sulphate, aluminium potassium sulphate dodecahydrate, tartaric acid, and phosphomolybdic acid). The two scoured samples were further mordanted in a beaker prior to dyeing using 1% of each of the chemical mordants at 60 °C for 30 min with a material-to-liquid ration of 1:20 w/v.

2.7. Dyeing procedure

The samples treated with or without mordants were dyed in the dye baths with a dye extract-to-liquor ratio of 1:50 w/v for *C. longa* and 1:12.5 w/v for *T. stans* at different temperatures of 40, 60, and 80 °C using a stirrer heater (model hot plate magnetic stirrer MS-H280-Pro). The volume of the extract used in dyeing was dependent on the weight of the material to be dyed, *i.e.,* material-to-dye extract 1:0.8 w/v. After 20 min, 10 mL of sodium sulphate (1:10 w/v, 0.72 M) was added and the dyeing was completed 40 min after. The dyed fabrics were rinsed in cold water and spread in a shade (away from direct sunlight for 24 h) (Scheme 1).

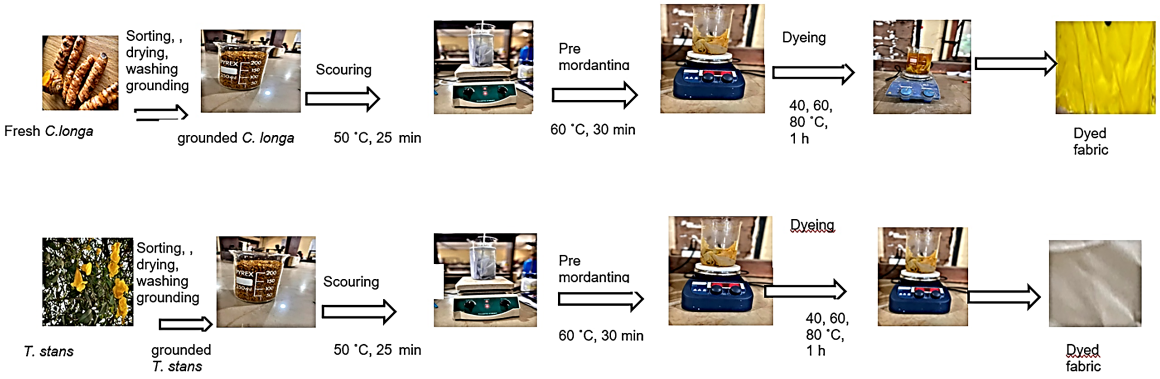
2.8. Colour fastness test

The dyed materials were tested for lightness and washability. The colour fastness was rated by the loss of depth of colour in the original samples. Light fastness was analysed by exposing the dyed materials to direct sunlight for 24 h and then comparing them with the original samples for the loss of depth of colour. The wash fastness was carried out by washing the dyed fabrics with a non-ionic soap, So Klin (1 g/L) (Chandra et al., 2012).

3. Results and discussion

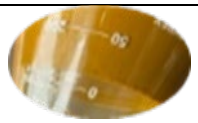
Dyeing clothes with turmeric is an excellent way of dyeing because it produces a vibrant, warm yellow colour on natural fabrics even without the use of mordants, whereas some natural plants require the use of mordants (mordants help in fixing the dye to the fabric). The extract of natural dye solution from the rhizomes of turmeric and the petals of *T. stans* at different powdered concentrations was used in dyeing cotton and silk at 60 min using different mordants (phosphomolybdic acid, ferrous sulphate, tartaric acid, and aluminium potassium sulphate dodecahydrate) at 40, 60, and 80 °C to optimise the dyeing process. The exhaustion and fixation processes of the dyeing were achieved using Na_2SO_4 and Na_2CO_3, respectively, on both cotton (cellulosic) and silk fabric (proteinous fibre) (Moula et al., 2022). The pH and absorbance of the resulting solution were measured before and after dyeing. The effect of mordant was studied with varied colour shades on the cotton and silk by determining the light and wash colour fastness properties of the optimised premordanting fabric. Table 1 shows the wavelengths and absorbances of each solvent used for extraction. The fresh extracts were used for dyeing. For both plant extracts, the ethanolic extracts had the highest wavelength and the highest absorbance. Thus, the dyeing of fabrics was done using the extracts derived from ethanol as it presented a more intense colour.

Figures 3 and 4 show the functional groups of *C. longa* and *T. stans,* respectively. The spectrum of *C. longa* showed major bands at 3362.1 cm^{-1} (Alcohol O-H stretching intermolecular bond of the free hydroxyl group of phenol, str broad), 2926.0 cm^{-1} (alkane sp^2 C-H stretching vibration, med), 1740.7 and 1684.8 cm^{-1} (C=O stretching vibration of ***β***-diketone, wk), 1625.1 cm^{-1} (C=C stretching vibration of ***β***-diketone, med), 1584.1 and 1513.3 cm^{-1} (N=O stretching, str), 1449.9.1 cm^{-1} (CH_2 angular deformation vibrations, med), 1379.1 cm^{-1} (C-H symmetric deformation vibrations in the CH_3, med), 1282.2 cm^{-1} (C-O, med), 1136.8 cm^{-1} (enol, C-O-C stretching, med), 1028.7 cm^{-1} (C-O stretching) and 976.6 cm^{-1} (C=C stretching vibration, med). The stretching vibrational band at 750 cm^{-1} corresponded to the ortho (1,2) of a substituted out of phase hydroxyl and O–CH_3 bond at the aromatic ring. These findings corroborated those of other researchers on curcumin (Pandit et al., 2015; Rohman et al., 2015; Van Nong et al., 2016; Charan et al., 2022). The spectrum of *T. stans* showed major bands at 3268.9 cm^{-1} (Alcohol O-H stretching vibration, intermolecular bonded, str broad), 2926.0 cm^{-1} (Alkane C-H stretching vibration, med), 1666.1 cm^{-1} (C=O stretching vibration of ketone, wk), 1416.4 (CH_2 angular deformation vibrations, OH, med), 1248.7 cm^{-1} (C-O stretching, med), 1032.5 cm^{-1} (C-O-C stretching, str), 920.7 cm^{-1} (C=C stretching, str), 864.57 and 820.0 cm^{-1} (aromatic stretching, med) and 775.3 cm^{-1} (aromatic stretching, med). This was in line with other researcher findings (Lavudi et al., 2023). The spectral pattern correlated with the rutin spectral pattern (Ismail et al., 2023).



Scheme 1. Chemical processes of extraction of dye to dyeing from *C. longa* and *T. stans*.

Table 1. Wavelength, absorbance and transmittance of different extracting solvents of *C. longa* and *T. stans*.

Solvent	*C. longa*		*C. longa* extract	*T. stans*		*T. stans* extract
	Wavelength (nm)	Absorbance		Wavelength (nm)	Absorbance	
Ethanol	485	1.767		485	3.000	
Ethyl acetate	424	1.699		425	1.170	
n-Hexane	362	1.764		362	2.288	
Distilled water	315	0.766		315	0.313	

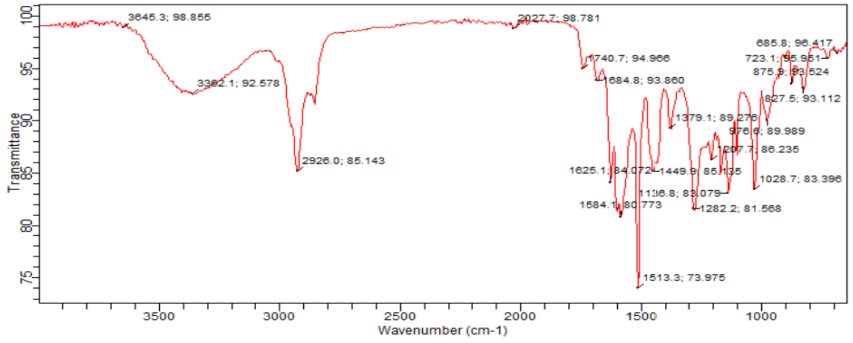


Figure 3. FTIR Spectrum of *C. longa*

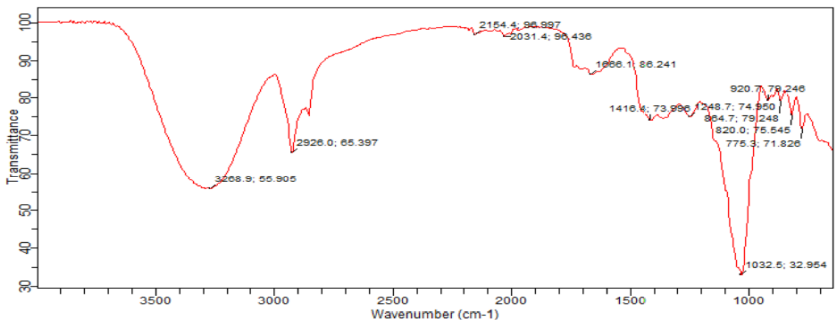


Figure 4. FTIR Spectrum of *T. stans*.

The UV-Vis spectra of *C. longa* and *T. stans* were in the region of 300–500 nm (Figure 5). All the solvents of *C. longa* had peaks within 227–485 nm in the UV-visible and near-infrared regions. The ethanolic extract had peaks at 362 nm, 424 nm, and 485 nm. The absorption bands at wavelength 424 nm with absorbance 0.514 were for the low energy π – π* transition of C=O. This was correlated with the excitation of curcumin reported (Kim et al., 2013). All the solvents of *T. stans* had peaks within 261-460 nm. The ethanolic dyeing extract showed different absorbance bands at 272, 374, and 400 nm at pH 6.8. The ethanolic extract of *T. stans* has been reported to have rutin (Singh et al., 2020). The identified peaks were in line with those reported for rutin (Li et al., 2019). The absorption bands were the result of π – π* and n – π* transitions of C=C and C=O, respectively. This was in line with the excitation reported (Devi et al., 2021).

The pH of each mordant before and after dyeing is presented (Tables 2 and 3) and (Figures 6 and 7). pH correlates with temperature changes; as the temperature increases, the pH of both extracts decreases slightly. The dye bath of the extracts was acidic, ranging from 5.34 to 6.87. The hydrogen ion of the mordant contributed to the pH of the dyeing bath. However, the pH of the premordanting dye bath for *C. longa* was more acidic after dyeing with ferrous sulphate, aluminium potassium sulphate dodecahydrate, tartaric acid, and phosphomolybdic acid, ranging between 3.35 and 4.56. Meanwhile, *T. stan's* dyeing bath became more acidic after adding ferrous sulphate, ranging between 3.69 and 3.78, than tartaric acid, phosphomolybdic acid, and potash alum, ranging between 3.60 and 4.60. The dyeing bath with the lowest absorbance had the highest dyeing capacity (Moula et al., 2022). The fabrics from the bath medium with the most acidity after dyeing had better light- and wash-fastness abilities. The outcome shade of colour reflects that of curcumin and rutin, as they are yellow in acidic mediums (Khankaew & Panichayupakaranant, 2023).

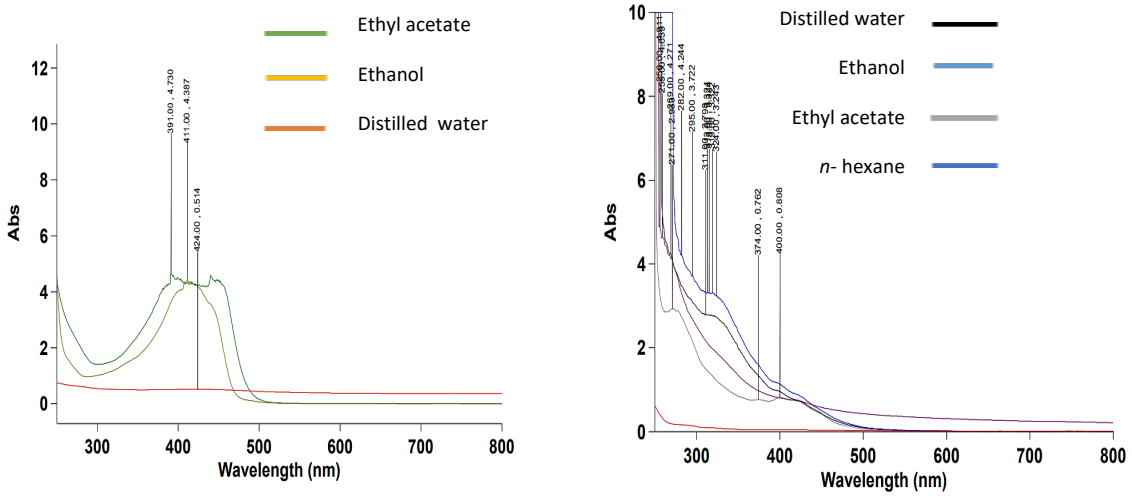


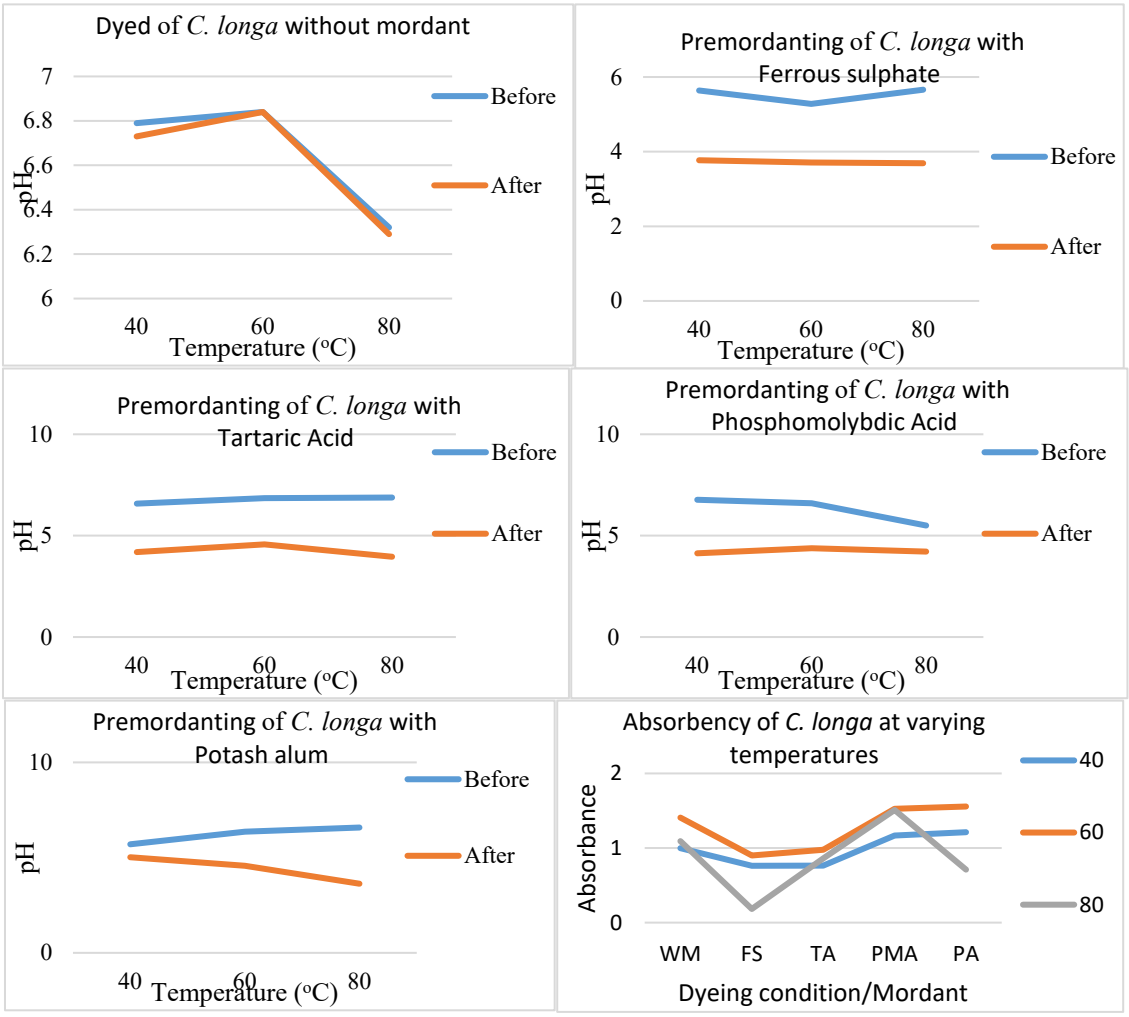
Figure 5. UV-Vis spectroscopy spectra for extract of *C. longa* and *T. stans* dye at various solvents.

Table 2. Studied parameter in dyeing cotton and silk fabrics with *C. longa* extract.

S/N	Dyeing condition/ Mordants	Temperature (°C)	Time (min)	pH before dyeing	pH after dyeing	Absorbance after dyeing
1	Dyed without mordant	40	60	6.66	6.45	0.997
		60	60	6.56	6.00	1.407
		80	60	6.87	6.84	1.090
2	Premordanting with Ferrous Sulphate	40	60	6.53	3.72	0. 762
		60	60	6.54	3.52	0.900
		80	60	6.59	3.56	0.183
3	Premordanting with Tartaric Acid	40	60	6.36	3.81	0.860
		60	60	6.54	4.56	0.976
		80	60	6.36	3.98	0.765
4	Premordanting with Phosphomolybdic Acid	40	60	5.34	3.87	1.167
		60	60	5.64	4.25	1.526
		80	60	5.78	4.32	1.510
5	Premordanting with Potash Alum	40	60	6.76	3.36	1.212
		60	60	6.01	3.67	1.564
		80	60	5.80	3.74	0.710

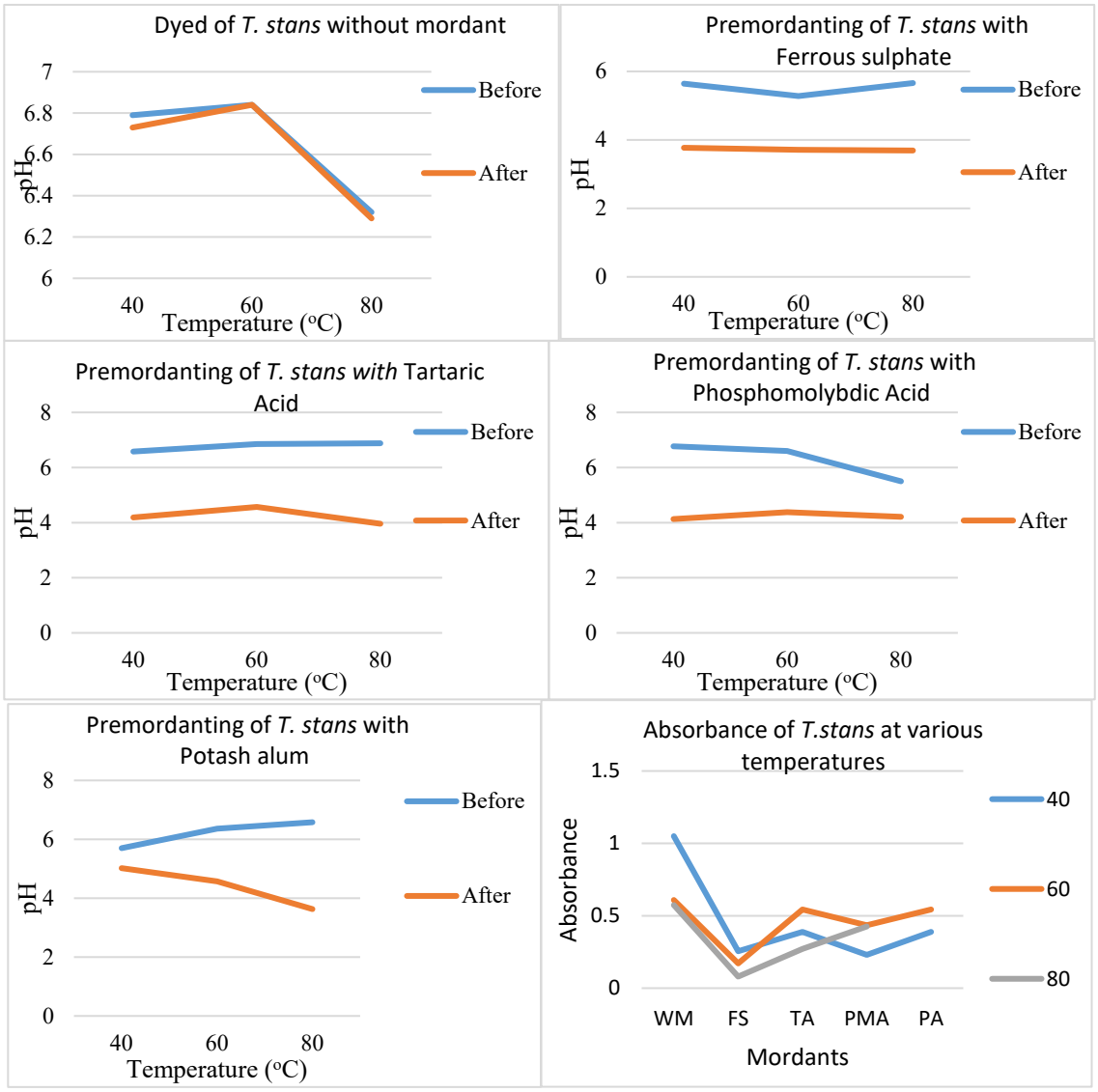
Table 3. Studied parameter in dyeing cotton and silk fabrics with *T. stans* extract.

S/N	Dyeing condition	Temperature (°C)	Time (min)	pH before dyeing	pH after dyeing	Absorbance after dyeing
1	Dyed without mordant	40	60	6.79	6.73	1.050
		60	60	6.84	6.84	0.609
		80	60	6.32	6.29	0.574
2	Premordanting with ferrous sulphate	40	60	5.64	3.77	0.255
		60	60	5.28	3.71	0.171
		80	60	5.66	3.69	0.080
3	Premordanting with Tartaric Acid	40	60	6.58	4.19	0.389
		60	60	6.85	4.57	0.543
		80	60	6.88	3.96	0.271
4	Premordanting with Phosphomolybdic Acid	40	60	6.77	4.13	0.230
		60	60	6.60	4.38	0.435
		80	60	5.50	4.21	0.426
5	Premordanting with Potash Alum	40	60	5.70	5.02	0.389
		60	60	6.36	4.57	0.543
		80	60	6.58	3.63	0.271



WM (without mordants), FS (iron (II) sulphate), TA (Tartaric Acid), PMA (Phosphomolybdic acid) and PA (Potash alum).

Figure 6. Graphical representation of the pH before and after dyeing using different mordants and absorbance of *C. longa* at varying temperatures.



WM (without mordant), FS (ferrous sulphate), TA (tartaric Acid), PMA (phosphomolybdic acid) and PA (Potash alum).

Figure 7. Graphical representation of the pH before and after dyeing using different mordants and absorbance of *T. stans* at varying temperatures.

The dyeing temperature plays an important role in dyeing, as a low temperature will result in complete dyeing, whereas a high temperature may result in hydrolytic degradation of dyes. Hence, temperatures of 40–80 °C were chosen. The dyeing ability of cotton and silk fabrics with natural dye extracts and the performance of the washing and light colour fastness tests using different mordants are presented (Tables 4 and 5). The maximum dyeing colour strength for dyed fabric with *C. longa* was obtained at 80 °C at all dyeing conditions. At that temperature, the cloth, with or without mordant, absorbed the dye colourant from the dyeing bath. Therefore, 80°C is the optimised temperature (Sarker et al., 2020). Meanwhile, *T. stans* found that the maximum dyeing colour strength was obtained from dyed fabric samples at 80 °C for fabrics dyed without mordant and that of ferrous sulphate. The shade of *T. stans* dyed cloth is similar to the work of Arunkumar and Yogamoorthi, (2014). Although the strength of each dyed fabric was found to be greater at 80 °C, this is due to the increase in kinetic energy leading to an increase in the diffusion of the dyeing molecule inside the cotton and silk fabric at a high temperature for a long time.

Extracted dye from *C. longa* and *T. stans* had varying wash and light colour fastness properties with each mordant on cotton and silk fabrics. The inability of a dye to fade is an inherent property of the dye chromophore (*C. longa*, C=O, C=C), which might be affected by auxochrome (*C. longa*, OH). The wash fastness property is the resistance of the dyed fabric to colour loss. It is influenced by the degree of dispersion of the dyed fabric. In some of the dyed fabrics, the performance was rated within the highest range of 9–6 as the most dyed fabric and the lowest range within 4–1. For wash fastness, it was observed that ferrous sulphate showed excellent wash fastness results on both fabrics compared to other mordants, as it made complexes in the octahedral configuration of coordination six with CH_2O- of cellulose and NH_3^+ and COO^- of silk (Habib et al., 2024; Musinguzi et al., 2019) (Figure 8 and 9). In the tables 5 it was evident that dyeing with ferrous sulphate as mordant at temperatures of 80 °C and 60 °C had the highest light colour fastness property, as well as phosphomolybdic acid. Although dyed fabrics with potash alum showed moderate fading to light at 80 °C, dyeing without mordants and dyeing with tartaric acid gave the lowest results even at 80 °C. This was in line with other researchers finding (Habib et al., 2024; Onal et al., 2020). The table 4 shows the effect of wash and light colour fastness on cotton and silk. All dyed cotton and silk fabrics gave a poor wash-fastness result except that of tartaric acid and ferrous sulphate for *T. stans* and without mordants for *C. longa*. The mordants had a low effect value on wash fastness at all temperatures except for the ones mentioned above. It was illustrated that the various values of colour shade for *C. longa* and likewise that of *T. stans* denoted different shades of yellow and brown on the effect of the auxochrome. The experimental outcome indicated that the turmeric dye used at 80 °C has promising results on both cotton and silk fabric. The molecular structure of the dye influenced the lightfastness ability, as cotton fabric was more dyed than silk fabric because of stronger H-bonding with the auxochrome OH than the NH_2^+ of silk. This might be a result of the oxidation and reduction processes that took place on the dyed fabric.

Table 4. Dyed colour, wash and light fastness shade of cotton and silk dyed with *C. longa* and *T. stans*.

Mordant	Fabric	*C. longa*			*T. stans*		
		Dyed shade	Test		Dyed shade	Test	
			light	wash		light	wash
Without Mordant	Cotton						
	Silk						
Phosphomolybdic Acid	Cotton						
	Silk						
Tartaric Acid	Cotton						
	Silk						
Ferrous Sulphate	Cotton						
	Silk						
Potash Alum	Cotton						
	Silk						

Table 5. Fastness properties of dyed cotton and silk samples (*C. longa* and *T. stans*) at 1 h.

Mordant	Fabric	Temperature (°C)	*C. longa*			*T. stans*		
			Dyed shade	Test		Dyed shade	Test	
				light	wash		light	wash
Without Mordant	Cotton	40	4	-	2	1	1	1
		60	7	2	2	2	1-2	1
		80	9	6	2	2	2	-
	Silk	40	5	-	3	-	-	-
		60	6	3	1	-	-	-
		80	8-9	5	2	-	-	-
Phosphomolybdic Acid	Cotton	40	6	-	2	2	1	1
		60	7	1	3-4	2	1	1
		80	8	2	1	3	1	1
	Silk	40	3	-	1	-	-	-
		60	5	-	1-2	-	-	-
		80	8	4	3	-	-	-
Tartaric Acid	Cotton	40	6	1	5	-	-	-
		60	8	1	3	1	1	1
		80	8	1	2	1	1	1
	Silk	40	5	1	3	1	-	-
		60	6	1	1	1	-	-
		80	6	2	1	1	-	-
Ferrous Sulphate	Cotton	40	6	2	5	4	2	4
		60	9	2	9	5	4	2
		80	9	2	7	6	1	4
	Silk	40	5	2	4	4	1	3
		60	8	1	8	3	1	3
		80	9	1	7	3	2	-
Potash Alum	Cotton	40	8	-	2	1	1	1
		60	7-8	-	2	3	1	1
		80	9	-	5	3	3	1
	Silk	40	8	1	3	-	-	-
		60	8	-	3	1	1	1
		80	9	-	6	1	1	1

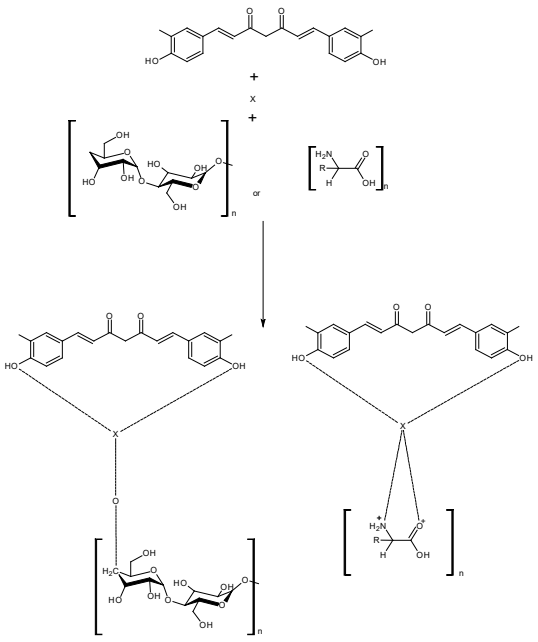


Figure 8. The dyeing proposed mechanism of cotton and silk fabrics with *C. longa* extracts.

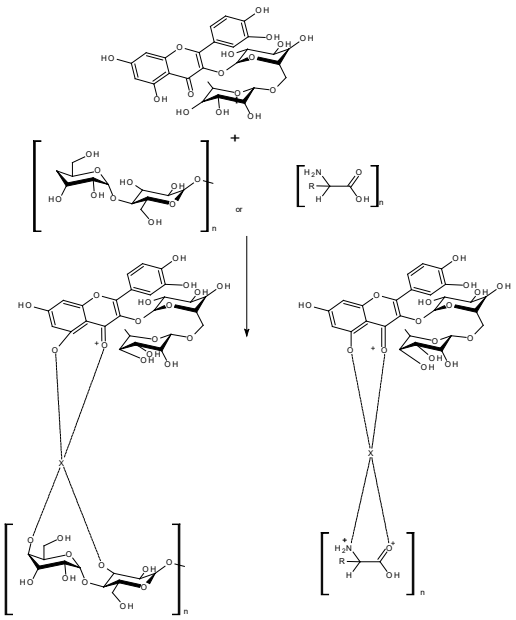


Figure 9. The dyeing proposed mechanism of cotton and silk fabrics with *C. longa* extracts.

4. Conclusion

Cotton and silk fabrics were dyed using natural dyes that were extracted from *C. longa* and *T. stans*. The colour fastness and washability of both textiles were demonstrated by dyeing them at different temperatures and with various mordants. Ferrous sulphate and aluminium potassium sulphate dodecahydrate showed excellent results on both fabrics. Cotton was better dyed than silk, demonstrating a better option for the fabrics at 80 °C and thus having good colour efficiency. The dyeing intensity and colour fastness increased with the dyeing temperature and the acidity of the dyeing bath.

Conflict of interest

The authors have no conflict of interest to declare.

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