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MODIFICATION AND APPLICATION OF DYE EXTRACT FROM TECTONA GRANDIS ON COTTON FABRIC

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Abstract

The natural dye was extracted from *Tectona grandis* using a soxhlet extractor, and a percentage yield of 16.84% was obtained. The color of the dye extract is maroon, and after the dye extract was modified, the color changed to brown. The modified dye was characterized using FTIR, AMF, and UV-visible spectroscopy. The results of the FTIR suggested the presence of C-H, C=C, C=O, N-H, C-O-C, C-Cl, and C-Br functional groups. The AFM suggests that the area roughness is 629.9 nm in the 25μm×25μm scan area. The UV shows a maximum wavelength of 581 nm with an absorbance of 0.074. The chromophore of the modified dye extract is -N=N- and C=O. The modified dye was applied to the cotton fabrics. The color fastness to washing shows that 3–4 and 4 were experienced for color change and staining, respectively, while the color fastness to rubbing shows that 4-5 and 4 were experienced for dry and wet rubbing, respectively. The outcome of color fastness shows that the modified dye has a good affinity to remain on the fabric. We therefore recommend the use of different kinds of mordants to improve the affinity of cotton fabric.

Keywords: Cotton fabric, Dye, Extraction, Modification, *Tectona grandis*

INTRODUCTION

Teak leaf (*Tectona grandis*), a large deciduous tree of the family Verbenaceae, or its wood, is one of the most valuable timbers. Teak has been widely used in India for more than 2,000 years. The name teak is from the Malayalam word tēkka. Locally, it is used as a chew stick for the treatment of toothache and fertility-related issues in women. It is also used to relieve gastro-intestinal complaints, inflammation, joint pain, and diarrhea (Venkatesh et al, 2023).

Natural dyes are a non-toxic alternative to conventionally used synthetic dyes that are causing irreversible damage to the planet (Merdan et al, 2017). By using natural dyes, there is a direct cutback on the toxic chemicals being released that are associated with synthetic dyes (Adeel et al, 2019). Synthetic dyes are not environmentally friendly as their synthesis involves extreme conditions such as high pH, high temperature, strong acids, and heavy metal catalysts. Synthetic dyes are toxic, carcinogenic, and can cause skin and eye irritation (Mehta et al, 2021). There are huge applications of natural dye on textiles, so it is imperative to promote technology for extraction (Kulkarni et al, 2011).

Joshua et al. (2023) studied the production and testing of *Baphia ntida* stem dye and its application to cotton fabric. It was observed that the red dye extracted from *Baphia nitida* possesses intrinsic affinity for cotton fabric. The observed affinity of the dye extracts for the textile substrates used for the study may be due to the presence of santalins and santarubin compounds. The FTIR characterization of the dye extract also suggested the presence of OH, CH, C≡N, C≡C, C=O, N=O, C=C, C-Cl, and C-Br functional groups in the dye components. The chromophores in the dye extract were N=O and C=O. The GC-MS separated and identified 30 compounds. Among the compounds identified from the dye extract, benz(a)anthracene, 7,8-ddimethyl, had the highest percentage area (35.09%), and 1,3,5-triazine, 2,4,6-ttriamine had the lowest percentage area. There are thousands of plants and animals that contain colorants that can be used as natural dyes. This present study is therefore focused on the extraction, characterization, and application of dye extract from *Tectona grandis (Teak leaf)* on cotton fabric. The aim of this research work is to extract, characterize, and apply the natural dye extract from *Tectona grandis (Teak leaf)* to cotton fabric. The aim of this research work is to modify the natural dye extract from *Tectona grandis* and apply it to cotton fabric.

Plate 1: *Tectona grandis* (Teak leaf)

MATERIALS AND METHODS

Sampling and sample preparation

The teak leaf (*Tectona grandis*) was collected from Wukari LGA in Taraba State. The sample was shade dried and ground into powder form using a mortar and pestle, which was ready for extraction.

Extraction of natural dye

The sample was measured using an analytical weighing balance. 200 g of the sample was partitioned into five portions, each containing 30 g of the sample, and 200 mL of absolute ethanol was added into the round bottom flask for each of the 30 g of samples fitted into the thimble for extraction. The heating mantle was on, and extraction was done for 6 hours on each of the samples. The temperature for extraction was 78.37 °C on the sample, which is the boiling point of ethanol. A rotary evaporator was used to remove excess solvent, leaving the dye in a dry state.The percentage yield and color were determined for the purified dye samples (Rather et al, 2020).

Modification of the dye extract

Modification was done by adding 1 ml of 1% sulfonic acid under a control condition, such as specific temperature and pH, to 1 g of the dye extract (Taleb et al, 2020).

FT-IR spectroscopy analysis

The dye extract was measured with an FTIR spectrophotometer using a Shimadzu IR prestige 21 spectrometer in the wavelength range of 400-4000cm.

AMF (Atomic Force Microscopy) analysis

AFM (Atomic Force Microscopy) TM-AFM model, results conducted on teak leaf extract revealed likely provided detailed information on the surface morphology and topography of the dye leaf. This technique is crucial for characterizing samples at the nanoscale level, offering insights into their size, shape, and distribution.

UV-Visible spectroscopy analysis

The dye extract was introduced in a quartz cell (lcm pathway) and measured with UV-Vis spectrophotometer. Scans from 200 to 800nm were performed in to generate the characteristic absorption spectra of the sample.

Scouring Process

The Scouring process was carried out using 3M of sodium hydroxide. To each of the beakers labelled A, B and C 50ml of the prepared sodium hydroxide was used to carry out the scouring process for 1 hr 100°c (Taleb et al, 2020).

Bleaching process

To each of the beakers labeled A, B, and C 3 M of sodium hypochlorite was measured with a measuring cylinder, and 100 ml of the prepared solution was used to carry out the bleaching process for l hr at 100 °C (Sannapapamma et al, 2022).

Preparation of dye bath

To prepare the dye bath, lg of the dye extracted was measured into three 250-ml beakers labeled A, B, and C. 1 ml of 1% sulfonic acid was added to each of the beakers containing the dye extract, which made the dyes dissolve, and this was diluted to 50 ml (Liu et al, 2020). The ratio of the dye extract to sulfonic acid in water is 1:1:50.

Dyeing the cotton fabric

To the dye bath solutions above, 4x4 cm of fabric was introduced. The dye bath is heated gently, and the fabrics leave until they have absorbed the color. The dyeing process commenced and lasted 1 hour at 100 °C. When the dyeing process was completed, the materials were removed from the dye bath and allowed to air oxidize for 10 minutes, after which they were rinsed with cold water to remove loose dye particles that adhered to the surface of the dyed materials. The dyed fabrics were then air dried, after which the fastness properties were tested (Karabulut & Atav, 2020).

Wash fastness properties

Procedure: The dyed fabric was first cut (4x4 cm), after which the undyed white fabric was cut (4×4) and machine stitched together to give one piece of fabric. 100 ml of water was measured with a measuring cylinder, and 3 g of detergent (Viva Plus) was weighed using a weighing balance and dissolved in the 100 ml of water contained in the beaker. The stitched fabric was introduced into the detergent solution, stirred vigorously for 10 minutes, and rinsed and dried at room temperature (Geetam et al, 2017).

Rubbing fastness properties

Procedure: The dyed fabric was first cut at 4x4 cm, after which the undyed white fabric was cut (4×4) for both dry and wet rubbing. For dry rubbing, the undyed white fabric was rubbed against the surface of the dyed fabric for 10 minutes. For wet rubbing, the undyed white fabric was first immersed in water (wet) and rubbed against the dyed fabric for 10 minutes (Samanta & Agarwal, 2020).

RESULTS AND DISCUSSION

Extraction of dye

The Soxhlet extraction method was used in the extraction of the dye from Tectona grandis. Tectona grandis was pulverized and fed into the soxhlet extractor. Ethanol was used as a solvent, and the extraction was carried out for 8 hours. The temperature for the extraction was 78.37 °C, which is the boiling point of ethanol. The result of the extraction of dye from Tectona grandis, as described in Table 1, showed that 200 g of the sample was used for the extraction. After the extraction, the weight of the sample was reduced to 166.33 g, and the actual yield of dye extracted was 33.67 g. The percentage yield of the dye extract was 16.84%, and the color of the dye extract was brown. After the extraction modification was carried out, 1 ml of sulfuric acid was added to 1 g of dye extract, after which 50 ml of water gave it a brown color (Hassan, 2023).

Plate 2: Pulverized *Tectona gradis*

Plate 3 Dye produced from *Tectona grandis*

Table 1: Extraction of dye from *Tectona grandis*

Tectona grandis powder (g)	Weight after extraction and purification (g)	Actual yield (g)	Percentage yield (%)	Colour of the dye extract	Colour of modified dye
200	166.33	33.67	16.84	Maroon	Brown

FTIR Analysis of modified Dye Extract from *Tectona grandis*

The FTIR spectrum of the dye extract, as highlighted in Figure 1, showed a band at 2925.7859 cm1, which is due to the presence of C-H stretching vibrations of alkane. The band at 2620.1535 cm1 is assigned to the C=O stretching of carboxylic acid. In the spectrum of the dye extract, vibrations occurring at band 2347.0466 cm1 suggest the presence of the C=C group of conjugated alkane and the C-N of the cyanine group; a band at 1543.1111 cm1 is an indication of the presence of N-H stretching vibrations of amide. The band at 1156.0566 cm1 is assigned to the C-O–C vibrations of polysaccharide. The strong absorption band at 1083.5152 cm1 is assigned to the C-O group of carbohydrate, and the absorption bands at 869.7051 and 726.1495 cm1 indicate the presence of alkyl halides (C-Cl and C-Br) (Sanda & Liliana, 2021)

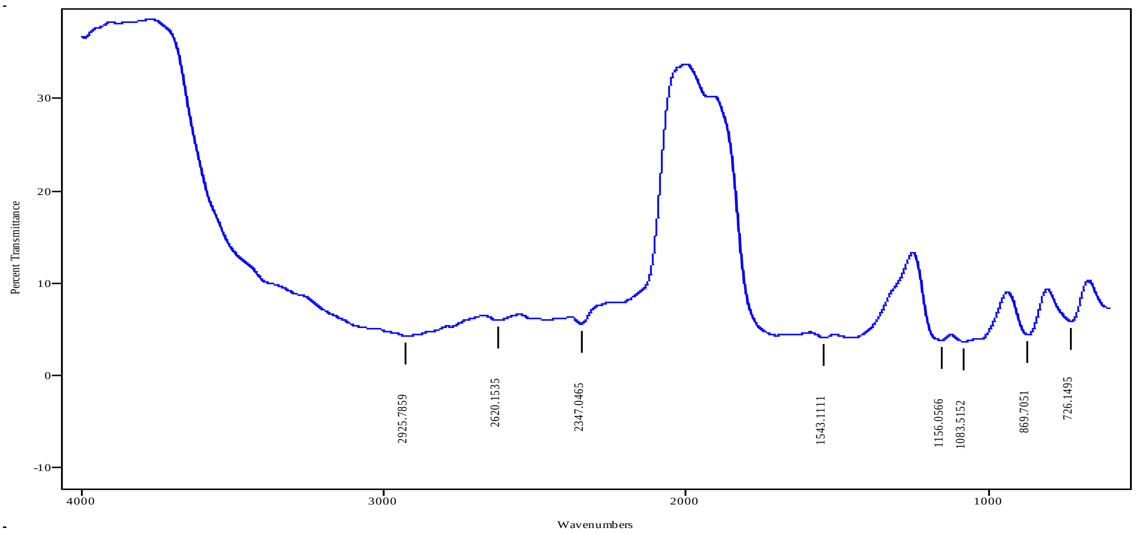

Fig 1: FT-IR spectra of the modified dye extract

AFM analysis of modified dye extract from *Tectona grandis*

The atomic force microscopy (AFM) of the modified dye extract, as shown in Fig. 2, was obtained in order to examine the surface morphological characteristics of the dye. Details of the surface structure of the modified dye extract at the nanometer scale were observed. A high degree of roughness was observed on the surface of the dye extract. The root mean square roughness of the dye extract was about 629.9 nm in the 25µm×25µm scan area. With a roughness value of 629.9 nm, the dye extract's surface exhibits a noticeable texture. Rough surfaces can have more active sites, potentially increasing the dye's reactivity or interaction with other substances. Understanding the surface characteristics is helpful since they can affect a number of things, including adhesion, light reflection, and interactions with other materials. The rough surface of the modified dye extract increases the surface area of the film, enabling more pomegranate dye to be adsorbed, which consequently increases the absorption of the incident light. The color distribution in the phase image of the dye was very uniform, which is an indication that the dye is uniformly distributed over the whole layer (da Conceição et al, 2023).

3D 2D

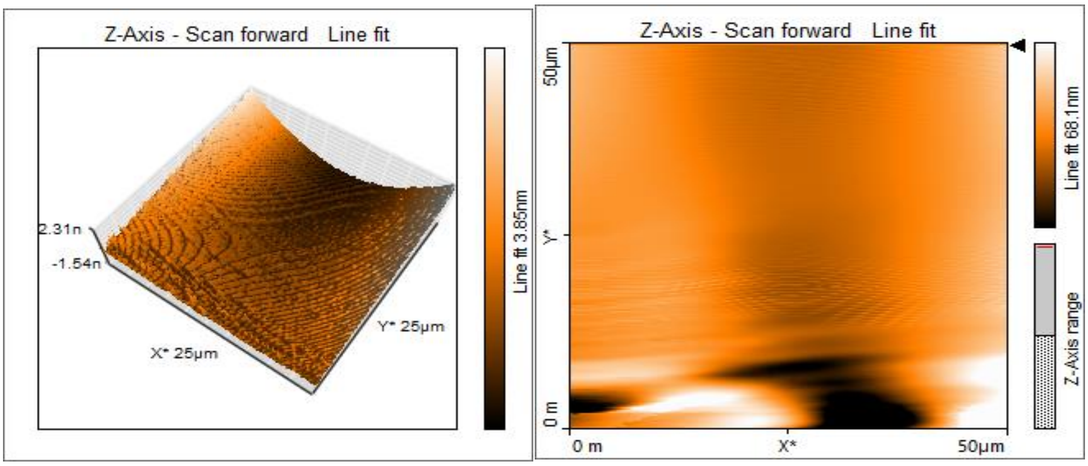

Figure 2. The 3D and 2D image of the modified dye extract from *Tectona grandis*

UV-Visible Spectrum of modified dye extract from *Tectona grandis*

The UV-visible dye-modified extract from *Tectona grandis,* as presented in Fig. 3, appeared at a maximum wavelength of 581 nm with an absorbance of 0.074. This is attributed to $\pi \rightarrow \pi^*$. This suggests that the chromophores N=N and C=O are present (Pandey et al, 2023).

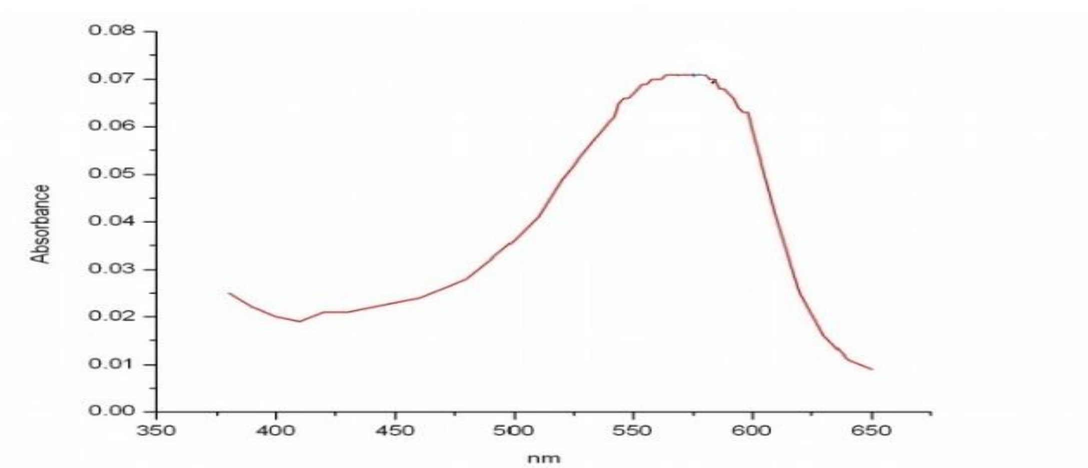

Fig 3: UV-Visible spectrum of the modified dye extract from *Tectona grandis*

Scouring and bleaching of Cotton fabric

The scouring and bleaching of cotton fabrics as described in Fig. 4 showed that three cotton fabrics with different weights were scoured with sodium hydroxide (NaOH) and bleached with sodium hypochlorite (NaClO). The results showed that there is a progressive decrease in the weight of fabric after scouring and bleaching due to the removal of natural wax and non-fibrous impurities, making the fabric permeantly white and brighter, and as such, the fabric is desized and the weight is reduced (Fried et al, 2022).

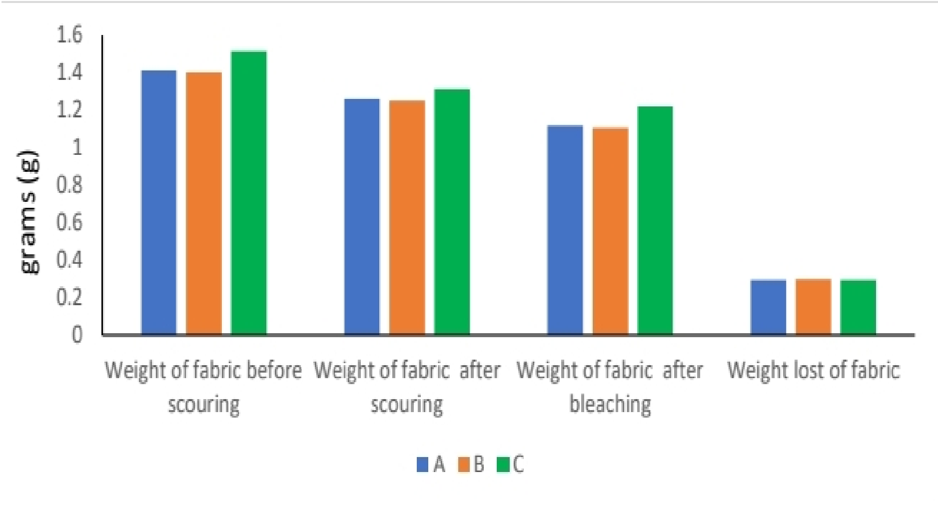

Fig.4 Scouring and bleaching of Cotton fabric.

Dyeing of modified extract on cotton fabric

The results of dyeing the cotton fabrics, which are given in Fig. 5, show that there is a progressive increase in the weight of the three different fabrics. This is due to the increase in absorbency power of the fabric, which increases the dye affinity for the fabric (Khattab et al, 2020).

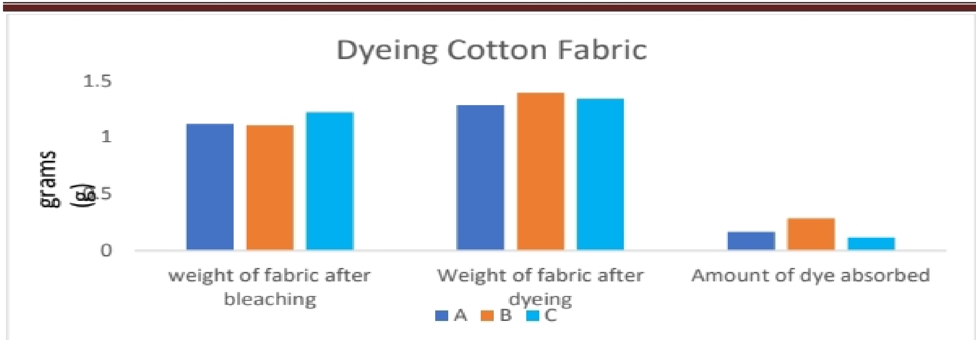

Fig.5: Dyeing of cotton fabric

Plate 3: Treated fabric and dyed fabric using the modify dye extract.

Wash Fastness properties of the dyed fabric

The results of the washfastness properties of the modified dye extract from *Tectona grandis* on cotton fabric, which were presented in Table 3, showed that when the modified dye was dyed without mordants, a fastness grade of 3–4 was experienced, which indicates fair to good fastness. And it was observed that the adjacent fabric, which is undyed, experienced a staining grade of 4, which indicates light staining (Otutu et al, 2012).

Table 3 Wash fastness properties of dyed fabric

Fabric type	Color change	Color staining
Dyed fabric	3-4	4

Wash fastness: 1- very poor; 2- poor 3-fair 4- good 5-excellent; Staining of adjacent white fabric: 1- deep staining; 2- significance staining; 3- moderate staining; 4- very light staining; 5- no staining.

Rubbling fastness properties of dyed fabric

The results of the rubbing fastness properties of the modified dyed fabric as described in Table 4 show that both dry and wet conditions gave rise to a rubbing fastness grade of 4-5, which indicates good to excellent for dry rubbing, and a rubbing fastness grade of 4, which indicates good for wet rubbing fastness (Periyasamy, 2022).

Table 4 Rubbling fastness of dyed fabric

Fabric Type	Dry rubbing.	Wet rubbing
Dyed fabric	4-5	4

Wash fastness: 1- very poor; 2- poor 3-fair 4- good 5-excellent

CONCLUSION

Natural colorant was successfully extracted from *Tectona grandis* using a soxhlet extractor and ethanol as a solvent. The color of the dye extracted is maroon, and the percentage yield is 16.835%. After the extraction, modification was carried out using sulfonic acid as a modifier, which changed the color of the dyed extract from maroon to brown. The modified dye was applied to cotton fabric without mordants. The results obtained in this study suggest that the brown color of the modified dye from *Tectona grandis* possesses an intrinsic affinity for cotton fabric due to the presence of -N=N- and C=O chromophores. The UV shows a maximum wavelength of 581 nm with an absorbance of 0.074. The FTIR characterization of the modified dye also suggested the presence of C-H, C=O, C=C N-H, C-O-C, C=O, C-Cl, and C-Br functional groups in the dye component, and the AFM suggests that the area roughness was about 629.9 nm in the 25μm×25μm scan area.

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