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Effects of Extraction and Mordanting Methods of Natural Dye from Teak Leaves on Coloration of Cotton Fabric

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Abstract

The study investigated effects of extraction and mordanting method of natural dye from teak leaves on coloration of cotton fabric. Specifically, it determined: effects of two extraction methods of natural dye from teak leaves on hue intensity of dye stuff, and time efficiency, colour shades; effect of mordanting on colour shades dyed of cotton fabric, and acceptability level of the dyed cotton fabric. It was an experimental research. Extracted dye was applied to mordanted and non-mordanted cotton fabric. Ten panelists evaluated dyed cotton fabric samples labeled. MM (maceration mordanted), DM (decoction mordanted), MNM (maceration non-mordanted), and DNM (decoction non-mordanted). Data were analyzed using mean. Major findings reveal, among others, decoction extraction proved more efficient, as it yielded a concentrated hue of the dye stuff, and required lesser extraction time; DM fabric sample yielded highest mean score of ($\overline{X}$= 4.00). Mordanted samples yielded deeper hue, and were more acceptable, with acceptability mean scores of ($\overline{X}$= 3.38) and ($\overline{X}$ = 4.00) for MM and DM respectively. It was concluded that teak leaves have dyeing potentials and can be used as a source of textile dye.

Keywords: Natural, Dye, Teak Leaf, Extraction, Mordanting, Methods, Cotton, Fabric, Effects.

Introduction

Natural dyes are dye stuffs derived from natural sources such as plants, animals and minerals resources which are renewable and sustainable. They are biodegradable substances that can be easily used without much health and environmental concerns (Pizzicato et al., 2023). Natural dyes can be obtained from our immediate environment and used to colour fabrics, foods, and other items for aesthetics and value addition. Prior to utilization, natural dyes are obtained from their original sources. In extracting dyes from their natural sources, different methods are employed for effective extraction. Salaudddin et al., (2021), elucidated dye extraction methods as techniques and processes used in isolating and obtaining colourants from natural sources such as plants, animals, or minerals resources, and converting them into suitable forms for dyeing purposes, thereby creating sustainable and eco-friendly dyes. Among the extraction methods, aqueous extraction is a

traditional method of obtaining colours from plant materials using water, with or without the addition of any other substance (Helmy, 2020). It includes processes such as maceration and decoction.

Maceration is a process in which plant parts; leaves, stem, seeds, fruits, are steeped in a liquid, typically a solvent like water, oil, or alcohol in room temperature for several hours while occasionally stirring it. This soaking allows the liquid to extract the dye colour from the plant material (Kumar et al., 2021). Decoction is a method of extracting compounds from plant materials, such as leaves, herbs, roots, bark, or woody substances, by boiling them in water or another suitable solvent to dissolve the chemical constituents in the plant material. It involves washing and drying the plant material, then mashing, shredding or cutting the material to allow for maximum dissolution and finally boiling in water to extract dye. It is the most common preparation method in various herbal medicine systems. Different natural dyes require specific techniques to ensure efficient dye extraction in different forms from their sources, as a technique effective for extracting a dye from its source, may not be suitable for another. The efficiency of dye extraction techniques is determined by measurable parameters that assess dye yield, quality, time factor, and sustainability. According to Bushra et al., (2018), some of these parameters include dye yield, concentration, purity, hue intensity, eco-friendliness, cost effectiveness, and time efficiency; an extraction technique is considered efficient when it outperforms other techniques being compared, in most of these parameters.

Natural dyes exhibit important properties that provide them an edge over synthetic dyes. Some of these properties include; biodegradability, non-toxic, non-allergic, environment-friendly, and renewable (Sankari et al., 2024). However, there are some limitations associated with the use of natural dyes: the need of mordant for dye fixation into the fabric, and possible low colour and light fastness. Despite these limitations, there is a need to revive the art of natural dyeing in recent years. This is largely due to increase in environmental concerns (Haji, 2023).

In order to overcome the colour adherence limitations of natural dyes, fabrics are subjected to treatment with a substance known as mordants, to improve the adhesion, permanence, and brilliance of dyes, by increasing the affinity of the fabric to the dye. Mordant, derived from the Latin word *mordere* which means, to bite, is applied to soften or weaken the internal parts of the fibres to be dyed before the dye colour is applied. According to Ezema et al., (2023), mordants are chemical agents which allows a reaction to occur between dye and fabric thereby aiding in fixing the colour to the fabric. This helps in improving the penetration of dye into a fabric, thereby reducing the running off tendency of the dye color during washing, rubbing, or exposure to sunlight, in essence, improves the fastness properties of fabrics (Nwonye et al., 2017).

There are plethora of plant resources which contain colourings in them, and they have the potentials to be utilized as natural dyes. Teak leaves among other plant parts like beetroots, madder roots,

pomegranate peels, turmeric rhizomes, insulina leaves, avocado seeds, heartwood of *nauclea diderrichii*, petals of rose, marigold, henna, contain significant colouring pigments that serve as natural dyes (Akubugwu et al., 2017).

Teak (*Tectona grandis*) is a tropical hardwood tree species in the family *Lamiaceae*. It is a large, deciduous tree that occurs in mixed hardwood forests. Teak is a large tree up to 40 meters tall with grey to greyish-brown branches, known for its high quality wood. The large, papery leaves of teak trees are often hairy on the lower surface. The leaves are ovate-elliptic to ovate, 15 - 45 centimeters long by 8 - 23 centimeters wide, in shape they resemble those of the tobacco plant (Qadariyah et al., 2018). Teak is native to south and Southeast Asia, but is naturalized, propagated and grown in Nigeria. Kusumawati et al. (2021), reported that teak leaf contains anthocyanin pigment which constitutes the appearance of red colour in utilization. Anthocyanin is one of the potential plant colour, and its contents in teak leaves serve as natural dyes for coloration (Kamboj et al., 2021).

Pensri et al., (2021), investigated the development of natural pigments from *Tectona grandis* leaves. The study extracted natural pigments from teak leaves, highlighting the sustainable use of agricultural waste. Soxhlet extraction method was employed, using ethanol as a solvent to obtain pigments, as ethyl acetate crude extract exhibited the highest intensity of colour. The effects of the type of substrate on the colour characteristics of the obtained pigments and the condition of the pigment preparation were determined. Similarly, the thermostability and photostability of the pigments were evaluated. While the reviewed study focused on pigment extraction from teak leaves, and the relationship between the amount of colour substances extracted and the polarity of the solvent, the present study determined an effective method of extracting dye from teak leaves in aqueous form. This review emphasizes the importance of ecofriendly dye extraction, and identifies the knowledge gap the present study addresses.

Purpose of the Study

The general purpose of the study was to investigate effects of extraction and mordanting methods of natural dye from teak leaves on coloration of cotton fabric. Specifically, the study determined:

1. effects of two extraction methods of natural dye from teak leaves based on hue intensity of dye stuff, and time efficiency.
2. colour shades obtained from natural teak dyes based on two methods of extraction.
3. effect of mordanting on colour shades of cotton fabric, dyed with natural teak dyes.
4. acceptability level of cotton fabric samples dyed with natural teak dyes.

Materials and Methods

***Design of the Study*:** The study adopted an experimental research design.

***Procurement of Materials*:** The fresh-young teak leaves were plucked from a teak tree situated along the Staff Quarters in MOUAU. The cotton fabric which is the substrate was purchased from Ariaria market Aba, Abia state. The alum (potassium aluminum sulphate), the mordanting agent was purchased from Ndioru market in Ikwuano, Abia state.

Extraction of dye: Maceration and decoction methods were used to extract dye from teak leaves as follows:

Maceration:

- 1kg of young teak leaves were thoroughly washed under running water, and shredded to smaller sizes.
- Shredded leaves were added to a plastic container containing 1 litre of water at room temperature.
- It was stirred at intervals for 24 hours for complete extraction, the mixture was strained to an extract.

Decoction:

- Extraction process was done by preparing 1kg of young teak leaves.
- Leaves were washed using running water and shredded into smaller sizes.
- Material was transferred to a sizeable pot, and a litre of water was added and boiled for an hour.
- Solution was left to cool and strained to an extract.

Mordanting of Substrate:

- Two pieces of cotton fabric were simmered for 5 minutes in a solution of dish soap, scrubbed and properly rinsed prior to mordanting.
- One fabric piece was charged in a solution of alum, used for the treatment of part of the fabric material. While second piece of fabric remained untreated.
- A litre of water was filled in a pot, a tablespoon of alum was added to it, and it was continuously stirred for proper dissolution, the fabric was submerged in the solution.
- This was brought to boil at 100°C and constantly stirred and simmered for one hour.
- Substrate was left to cool off, and soaked in the alum solution overnight.
- Fabric was removed from the pot and allowed to cool and dry.

Fabric Dyeing Procedure:

In maceration, the extract was obtained in aqueous form in a plastic container.

- Both fabric materials (treated and untreated) were submerged into the container and stirred at intervals, and left to process for an hour.
- For maceration mordanted, dyed treated fabric was transferred to the mordant solution, soaked for 15 minutes, aired for oxidation, and dried under a shade.
- For maceration non-mordanted, dyed untreated fabric was removed immediately after dyeing for oxidation, and was air dried under a shade.

In decoction, the concentrated extract was obtained in aqueous form.

- Dyeing was done in a sizeable pot into which extract solution of teak leaves was transferred in.
- Parts of the cotton fabric were submerged into the pot, and was simmered between 30°C - 35°C, and the dyeing was done for an hour.
- For Decoction Mordanted, the coloured treated fabric was squeezed and fixated in the mordant solution for 15 minutes, it was removed, and aired for oxidation.
- The fabric was rinsed in cold water to remove excess dye and dried under a shade.
- For Decoction non-mordanted, the untreated fabric was not submerged into the mordant solution after dyeing, but was aired and dried under a shade.

Sensory Evaluation of Samples of Dyed Cotton Fabric: Ten undergraduate students of Home Economics education served as a panel for the sensory evaluation of dyed samples of cotton fabric. Instrument for data collection was a 5-point hedonic scale of; 1 = Red, 2 = slightly deep red, 3 = hue not decided, 4 = deep red, 5= highly deep red. It was validated by three clothing and textile university lecturers. For data collection, each panel member samples were labelled MM (Maceration Mordanted), DM (Decoction Mordanted), MNM (Maceration Non-mordanted), DNM (Decoction Non-mordanted).

Data from the sensory evaluation were analysed using mean.

The likeability of each measured attribute were based on a 5-point rating scale. Mean scores greater than ($\overline{X}$= 3.00) were considered like, while mean scores less or equal to ($\overline{X}\leq$ 3.00) were considered dislike.

Results

Table 1: Effects of Two Extraction Methods of Natural Dye from Teak Leaves, and the Colour Shades Obtained from Natural Teak Dyes Produced from the Extraction Methods.

Extraction Methods	ET_1	ET_2	DCOFE	HIDS	TE
Maceration	24°C	24 Hours	Burgundy	Lower intensity	Low
Decoction	100°C	1 Hour	Amaranth red	Higher intensity	High

ET_1 = Extraction Temperature; ET_2 = Extraction Time; DCOFE = Dye Colour Obtained from Extraction; HIDS = Hue Intensity of Dye Stuff; TE = Time Efficiency.

Table 1 shows effect of decoction and maceration extraction methods of natural teak dye based on hue intensity and time efficiency, as well as the colour shades obtained from both methods of extraction. It reveals that decoction extraction method, extracted more concentrated pigments from the teak leaves within a shorter time, under high temperature. Decoction, yielded amaranth red, a vibrant reddish-purple colour. While maceration extraction method, under room temperature and within a longer time yielded burgundy, a lighter hue of reddish-wine colour. Thus, decoction is more efficient as compared to maceration, considering the hue intensity and time efficiency of the extraction process.

Table 2: Effects of Mordanting on Colour Shades of Cotton Fabric Dyed with Teak Dye

Extraction Methods	DCA_1	DCA_2	DCA_3
Maceration	Burgundy	Tawny	Burgundy
Decoction	Amaranth red	Russet	Amaranth red

DCA_1 = Dye colour after extraction; DCA_2 = Dye colour after dying mordanted fabric; DCA_3 = Dye colour after dying non-mordanted fabric.

Table 2 shows effect of mordanting on the colour shades of the teak dyed cotton fabrics, it described the colour obtained from the two extraction methods, and the colour observed after applying the dye on mordanted and non-mordanted cotton fabric. The table illustrates that maceration yielded a reddish-wine coloured dye, but after applying on a mordanted fabric sample, the fabric colour became tawny; reddish-brown. However, on application on a non-mordanted cotton fabric, the colour remained unchanged as the colour at extraction; reddish-wine colour. While Decoction yielded a reddish-purple colour at extraction, but on application on a mordanted cotton fabric, the colour changed to russet, a deep reddish-wine colour. While on a non-mordanted cotton fabric, it gave a reddish-purple colour, maintaining the dye's colour from extraction. There was colour change observed in mordanted cotton fabrics characterized by darker hues. In contrast, non-mordanted fabrics did not exhibit such colour change.

Table 3: Mean Ratings of Colour Shades of Samples of Teak Dyed Cotton Fabrics

S/N	Color shades	Samples	$\bar{X}$	Remark
1.	Red	MM	2.00	DL
		DM	2.50	DL
		MNM	3.50	L
		DNM	1.50	DL
2.	Slightly deep red	MM	2.80	DL
		DM	1.80	DL
		MNM	3.00	DL
		DNM	3.20	L
3.	Hue not decided	MM	2.00	DL
		DM	1.50	DL
		MNM	1.50	DL
		DNM	2.50	DL
4.	Deep red	MM	3.80	L
		DM	1.80	DL
		MNM	2.40	DL
		DNM	2.50	DL
5.	Highly Deep red	MM	3.00	DL
		DM	4.00	L
		MNM	1.00	DL
		DNM	3.00	DL

Attribute mean score $\bar{X}$> 3 is likeable, mean score $\bar{X}\leq$ 3 is disliked; MM = Maceration Mordanted; DM = Decoction Mordanted; MNM = Maceration Non-mordanted; DNM = Decoction Non-mordanted; DL = Dislike; L = Like

Table 3 shows the acceptability of cotton fabrics dyed with natural teak dyes, based on four samples, across five colour shades. Considering the most preferred samples, MM had a mean score of ($\bar{X}$ = 3.80) as deep red shade, while sample DM scored ($\bar{X}$= 4.00) as highly deep red, both samples were highly preferred. Whereas MNM sample scored ($\bar{X}$ = 3.50) in red shade, indicating a moderate preference. For the least preferred samples, non-mordanted samples; MNM & DNM, generally performed poorly, with the least scores. For undecided hue, the mean of all the samples were below ($\bar{X}$= 3.00) which indicated they were disliked. Ultimately, mordanted samples; MM & DM produced deeper, and more acceptable shades, while non-mordanted samples were mostly disliked. Thus, mordanted samples with deeper red hues; deep red and highly deep red, were most acceptable.

Discussion

It was revealed that the dye extract from teak leaves was soluble in the water solvent, both cold and hot, for maceration and decoction respectively. Menna et al. (2022) reported that the solubility of the dye material with the corresponding

solvent has an effect on the hue intensity of the dye colour. Thus, the solubility of the teak dye with water contributed to the increased intensity of the dye colour, and resulted to visible shades of red colour on the samples of cotton fabric. Kusumawati et al. (2021) revealed that this shades of red colour in teak leaves is as result of the anthocyanin contents present in cell of the leaf. Findings from Table 1 showed that the dye concentration was high on decoction extraction. A similar result was reported by Jeelene et al. (2017). It could be attributed to temperature, as the heat of the solvent comes in contact with the leaves the extracting power was more efficient (Helmy, 2020). Temperature as one of the operational conditions in fabric dyeing, is the main factor which affect the extraction efficiency of dye from the teak leaves (Ezema et al., 2023). At higher temperature, the solvent was able to extract larger yield of natural dyes from the teak leaves, this observation is congruent to that of Phromphen (2022). The improved extraction efficiency of both extraction methods, could be attributed to the cutting of the teak leaves into smaller sizes prior to extraction, which broke down the cell structure of the teak leaves, and enabled optimum extraction, this is consistent with Mohan and Sivakumar (2020), who reported that pre-extraction treatments of dye materials enhance the overall time efficiency of extraction. However, the increased extraction temperature in decoction, resulted in high time efficiency and hue intensity, as compared to maceration with low time efficiency and hue intensity, as a result of low extraction temperature. This finding contrasts the report of Lailatul et al. (2018), who reported that extraction time is directly proportional to the colour intensity of extracted dye material.

Findings in Table 2, reveal darker hues observed in mordanted samples, the colour observed after extraction and dyeing, revealed maceration as reddish wine, and light reddish brown respectively, and decoction as reddish purple, and deep reddish brown respectively, this could be linked to the interaction of the mordant alum, which was used in treating the fabrics (Charoensit et al., 2021). Alum played a role in intensifying the dye colour, this report aligns with that of Hossain et al. (2018) whose study revealed the potential of mordants in modifying dye colours. Similarly, Kusumawati and Santoso (2017), affirmed that some mordants have the ability to darken or brighten dye colours. This suggests that the use of mordants in dyeing is not only limited to increased dye uptake and permanence, but the use of various mordants in natural dyeing results in varying hue intensities. Findings on acceptability of samples fabrics dyed with natural teak dyes, show that mordanting enhances acceptability, as mordanted samples; MM and DM consistently yielded more liked scores, particularly for deeper hues. This suggests that mordants also improve the aesthetic appeal of dyed cotton fabrics. Findings also showed consumers' preference depicted by the panelists, for deeper hues, as the highest acceptability scores were for deep red and highly deep red, this indicates preferences for rich hues in fabrics (Choudhury & Butola, 2021).

Conclusion

This study has shown that shades of red natural dye can be extracted from teak

leaves effectively using decoction extraction method. Decoction extraction yielded higher dye concentration within a minimal time, compared to maceration extraction. The mordant alum intensified and modified the dye colour, resulting in deeper shades and higher acceptability of the mordanted fabric samples. Ultimately, operational conditions such as temperature, solvent type, and pre-treatment of dye-containing material, influence extraction efficiency and colour outcome of a dyeing process. It can be concluded that teak leaf extract is a good source of natural dye, producing shades of red colour.

Recommendations

In view of the results of the study, the following are recommended:

1. Additional research should be conducted on fabric dyeing with teak dye using different mordants to determine the consistency of the post-dyeing colour intensification that was observed with alum.
2. Further studies should ascertain the colourfastness properties of teak leaves, to washing, sunlight and perspiration.

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