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| RESEARCH ARTICLE

Sustainable Textile Dyeing Using Indigenous Plant Resources: A Practice-Based Model for Eco-Friendly Colouration in Nigeria

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| ABSTRACT

The escalating environmental and public health hazards associated with synthetic textile dyes have intensified global interest in natural, plant-derived colourants as sustainable alternatives. This study presents a practice-based model for eco-friendly textile colouration in Nigeria, drawing on indigenous plant resources abundantly available in Southwestern Nigeria. Fifteen plant materials were selected from three categories, leaves (neem, hibiscus/zobo, blood leaf/Justicia carnea, mango, and henna), tree barks (kapok/Ceiba pentandra, cashew/Anacardium occidentale, mango, neem, and guava), and roots/sheaths/peels (turmeric, brimstone/Morinda lucida, carrot, onion peels, and sorghum sheaths). Aqueous extraction was employed, and dyes were applied to cotton and silk fabrics using three mordants, alum, lemon juice, and cocoa pod ash solution, across pre-mordanting, simultaneous mordanting, and post-mordanting techniques. Spectroscopic characterization through UV-Vis spectroscopy and Fourier Transform Infrared (FTIR) analysis identified key functional groups including hydroxyl (O–H), carbonyl (C=O), and conjugated aromatic systems across all extracts. UV–Vis results revealed absorption peaks that validated the chromophoric properties of the extracts, with absorbance peaks from 3333.2 to 657 cm^{-1}, indicating variations in dye concentration and intensity. Fastness evaluation revealed that bark-derived dyes produced the highest ratings (Grade 4–5) on cotton, while alum mordanting consistently enhanced colour stability. The study proposes an integrated, practice-based model combining indigenous knowledge with modern analytical verification, demonstrating a viable pathway towards sustainable textile production, cultural preservation, and eco-entrepreneurship in Nigeria.

| KEYWORDS

Natural Dyes, Indigenous Plants, Sustainable Textile Dyeing, mordanting, FTIR, UV-Vis Spectroscopy, Nigeria, Eco-friendly Colouration

| ARTICLE INFORMATION

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1. Introduction

The use of plant-derived dyes for colouring textiles constitutes one of the oldest technological traditions in human civilization. Long before the commercialization of synthetic dyes in the nineteenth century, communities across Africa, Asia, and the Americas relied extensively on plant materials, roots, leaves, bark, flowers, and fruits, to impart colour to fabrics for functional, aesthetic, and sociocultural purposes (Cardon, 2007; Samanta & Agarwal, 2009). In Nigeria, this tradition is deeply embedded in the cultural identity of various ethnic groups, most notably the Yoruba

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of Southwestern Nigeria, whose practice of Adire, indigo-resist dyeing, represents one of the most sophisticated indigenous textile arts on the continent (Areo & Kalilu, 2013).

The invention of mauveine by William Henry Perkin in 1856 inaugurated an era of synthetic dye dominance that progressively displaced natural dyeing traditions. Synthetic dyes offered demonstrable advantages: a wider colour gamut, ease of production, greater consistency, and lower cost at scale. However, the global textile industry's heavy reliance on synthetic dyes has generated a cascade of environmental and public health crises. Untreated effluents from dyeing operations contaminate waterways with toxic, often carcinogenic compounds, including heavy metals and aromatic amines. These effluents resist biodegradation, persist in aquatic ecosystems, and pose significant risks to human health, including dermatitis, respiratory disorders, and carcinogenesis (Shahid & Mohammad, 2013; Singh et al., 2016).

These concerns have catalysed a global renaissance in natural dye research, driven by the convergence of sustainability imperatives, advancing phytochemical science, and growing consumer demand for eco-friendly textile products. Natural dyes derived from plant sources are broadly biodegradable, non-toxic, renewable, and in many cases exhibit additional functional properties, antimicrobial, antioxidant, and UV-protective, that synthetic dyes cannot replicate (Repon et al., 2023; Yadav et al., 2024). Nigeria presents a particularly compelling context for natural dye research and revitalization: the country's tropical ecology sustains an extraordinary diversity of dye-yielding plants, many of which remain underutilized and scientifically underdocumented.

Despite the recognized potential of Nigerian plant-based dyes, critical scientific gaps persist. Most existing literature originates from South Asian, East African, and European contexts, limiting its direct relevance to West African plant materials and dyeing conditions. Moreover, few Nigerian studies integrate the full cycle of dye production—extraction, application, mordanting optimization, spectroscopic characterization, and fastness evaluation, within a single coherent framework. There is even more limited work on affinity characterization of locally sourced dyes using contemporary analytical tools such as Fourier Transform Infrared (FTIR) spectroscopy and Ultraviolet-Visible (UV-Vis) spectrophotometry.

This article extracts and synthesizes findings from a doctoral research project conducted at Ladoke Akintola University of Technology (LAUTECH), Ogbomoso, Nigeria. The study systematically investigated the extraction, application, and affinity characterization of textile dyes from fifteen indigenously sourced plant materials, applying them to cotton and silk substrates under varied mordanting conditions. The overarching argument advanced is that locally available plant resources, processed through a structured practice-based methodology, can yield viable, aesthetically satisfying, and scientifically validated dye systems that offer a sustainable alternative to synthetic dyes in the Nigerian context. The article proposes a replicable eco-friendly colouration model grounded in both indigenous knowledge and contemporary science.

2. Literature Review

2.1 Natural Dyes: Sources, Classification, and Global Revival

Dye, in its broadest definition, is any substance used to impart colour to a material in a manner that exhibits permanence. Natural dyes are those derived from biological sources, principally plants, but also insects and minerals (Bushira et al., 2018). Plant parts exploited for dye extraction include leaves, roots, bark, flowers, fruits, seeds, and whole plants, each yielding distinctive chromophoric compounds depending on the species, growing conditions, and extraction method (Saxena & Raja, 2014). The global natural dye palette spans indigo (from Indigofera tinctoria), red madder (from Rubia tinctorum), saffron yellow (from Crocus sativus), and countless regionally specific colorants (Cardon, 2007).

The classification of natural dyes follows several schemes. Chemically, they may be grouped as flavonoids, anthraquinones, carotenoids, tannins, and indigoids, among others. By source, they are classified as plant, animal, or mineral dyes. By application mechanism, they fall into substantive dyes (those requiring no mordant), mordant dyes (which require metallic or organic fixatives), and vat dyes (which undergo reduction-oxidation during application) (Mutasim et al., 2018; Krizova, 2015).

The revival of natural dyes in the twenty-first century is well documented in the scientific literature. Krizova (2015) traces the trajectory of natural dye use from antiquity to the present, noting that contemporary environmental awareness and the health-consciousness of textile consumers have created renewed demand for plant-based colorants. Kothari et al. (2021) emphasize that natural dyes are not only eco-friendly but also present commercial opportunities in niche markets for artisanal and premium textiles.

2.2 Problems Associated with Synthetic Dyes

The case for natural dyes is substantially strengthened by the well-documented hazards of their synthetic counterparts. Synthetic dye manufacture and application generate highly toxic effluents containing heavy metals, aromatic amines, chlorinated compounds, and sulphur derivatives (Shahid & Mohammad, 2013). Akarslan and Demiralp (2015) report that textile workers engaged in synthetic dyeing operations are exposed to caustic soda and other hazardous chemicals, leading to occupational health hazards including respiratory disease and chemical burns. The mutagenic and carcinogenic properties of many azo dyes, the dominant class of synthetic dyes, have been confirmed through multiple epidemiological and toxicological studies (Divya et al., 2013; Sayed et al., 2013).

Nigeria's rapidly growing textile industry, combined with limited environmental regulation and enforcement capacity, makes the country particularly vulnerable to the adverse effects of synthetic dye pollution. The transition to plant-based alternatives is therefore not merely an aesthetic or philosophical choice but an ecological and public health imperative.

2.3 Mordants and Mordanting Techniques in Natural Dyeing

Mordants are substances that facilitate the bonding of dye molecules to fibre substrates, forming stable coordination complexes that resist washing and light exposure (Opoku-Asare et al., 2013). Metallic mordants such as alum (potassium aluminium sulphate), ferrous sulphate, and copper sulphate are the most widely used; however, growing interest in fully sustainable systems has prompted exploration of botanical mordants, including tannin, wood ash, and plant juice extracts (Ali et al., 2014).

The timing of mordant application distinguishes three major mordanting techniques: pre-mordanting, where fabric is treated with mordant before dyeing; simultaneous mordanting, where mordant and dye are applied concurrently; and post-mordanting, where mordant treatment follows dyeing (Geetha et al., 2013). Each technique influences the depth, uniformity, and fastness of the resulting colour. Mohammed (2015) and Miah et al. (2017) demonstrate that pre-mordanting generally yields the most consistent and colour-fast results, a finding corroborated by the present study.

2.4 Characterization of Natural Dyes

Spectroscopic characterization of natural dye extracts is essential for identifying chromophoric compounds, understanding dye-fibre interactions, and establishing scientific bases for quality reproducibility. Tassew and Zenebesh (2014) used UV-Vis spectroscopy to characterize natural dye extracts, demonstrating its utility in identifying absorption maxima corresponding to specific chromophores. Muhammadu et al. (2017) combined FTIR and UV-Vis analysis to identify functional groups in cashew fruit extracts, detecting anthraquinonoid and indigo-type chromophores.

FTIR spectroscopy provides molecular 'fingerprints' by measuring the absorption of infrared radiation at frequencies corresponding to specific chemical bond vibrations. This enables the identification of functional groups such as hydroxyl (O–H), carbonyl (C=O), and aromatic C=C bonds, which are the primary chromophoric and auxochromic systems in natural dyes (Dhanush et al., 2020). Recent studies emphasize the integration of these spectroscopic techniques in natural dye research to improve scientific understanding and support industrial scale-up (Yadav et al., 2024).

Despite this body of work, systematic characterization studies focusing specifically on West African and Nigerian plant-derived dyes remain scarce. This gap constitutes the primary scientific motivation for the present study.

3. Methodology

3.1 Research Design

This study adopted an experimental, practice-based research design, integrating field investigation, laboratory experimentation, and studio application. This tripartite approach was necessary to address the full spectrum of the research objectives: from identification and collection of plant materials through to chemical characterization and aesthetic evaluation of dyed fabrics. Mixed methods were employed, quantitative analysis for spectroscopic and fastness data, and qualitative appraisal for visual/aesthetic outcomes (see Table 1).

Table 1: Research Logframe Summary

S/N	Objective	Method	Data Type	Analysis
1	Identify dye-yielding plant parts	Field observation; literature survey	Plant names, local names	Frequency count; cross-tabulation
2	Extract dyes via aqueous extraction	Water bath extraction at 80°C, 1 hr	Dye solutions from 15 samples	Laboratory experimentation
3	Apply dyes with mordants on cotton and silk	Pre-, simultaneous, and post-mordanting	Dyed fabric samples	Visual and spectrophotometric
4	Characterize functional groups	UV-Vis spectroscopy; FTIR analysis (BOWEN University CURL)	Wavelength & absorbance data	Spectral interpretation
5	Evaluate fastness properties	Wash, light, and rubbing fastness tests (FUTA)	Grey scale ratings (1–5)	Comparative analysis by dye source, mordant, and fabric

Source: Adapted from the author's doctoral research logframe (2023)

3.2 Plant Material Selection and Sample Preparation

Using multi-stage sampling from an identified pool of 100 dye-yielding plant species, 15 plant materials were purposively selected based on availability, accessibility, and ecological provenance within Osun and Oyo States, Southwestern Nigeria (Table 2). These were organized into three groups: five leaves, five tree barks, and five roots/sheaths/peels, each contributing approximately 5% of the sampling frame.

Table 2: Selected Plant Materials for Dye Extraction

S/N	Common Name	Local (Yoruba) Name	Botanical Name	Part Used	Colour Yielded
1	Neem	Ewe Sepeleba	*Azadirachta indica A.*	Leaves	Yellow
2	Hibiscus (Zobo)	Ewe Zobo	*Hibiscus sabdariffa*	Leaves	Red / Pink
3	Blood Leaf	Ewe Eje	*Justicia carnea*	Leaves	Yellow, Purple
4	Mango	Ewe Mangoro	*Mangifera indica*	Leaves	Yellow
5	Henna	Ewe Laali	*Lawsonia inermis L.*	Leaves	Golden Yellow / Green
6	Kapok Tree	Eepo Igi Araba	*Ceiba pentandra*	Bark	Reddish Brown
7	Cashew Tree	Epo Igi Kaju	*Anacardium occidentale*	Bark	Brown
8	Mango Tree	Epo Igi Mangoro	*Mangifera indica*	Bark	Yellow
9	Neem Tree	Epo Igi Sepeleba	*Azadirachta indica*	Bark	Orange / Purple
10	Guava Tree	Epo Igi Guava	*Psidium guajava*	Bark	Grey / Black

11	Turmeric	Turmeric	*Curcuma longa*	Root	Golden Yellow
12	Brimstone Tree	Gbongbo Igi Oruwo	*Morinda lucida*	Root	Yellow / Red
13	Carrot	Karoti	*Daucus carota sp.*	Root	Yellow / Orange
14	Onion	Alubosa	*Allium cepa L.*	Fruit Peels	Orangish Yellow
15	Sorghum	Okababa / Dawa	*Sorghum bicolor*	Sheaths	Red, Wine

Source: Author's classification compiled from fieldwork (2023)

3.3 Aqueous Extraction Procedure
Aqueous extraction was selected as the primary method due to its environmental safety, cost-effectiveness, and alignment with traditional West African dyeing practice. Plant materials were washed, dried (52 hours for leaves; 7 days for barks and roots), ground to fine powder using electric grinders, and sieved. For each sample, 30g of powder was placed in a 500ml beaker with 500ml distilled water and heated in a water bath at 80°C for one hour. The resulting solutions were filtered through muslin cloth and stored in sealed, labelled containers. This procedure ensured standardized extraction conditions across all fifteen samples (Salauddin et al., 2021).

3.4 Fabric Preparation and Mordanting
Cotton (charmingQ) and silk fabrics, each cut to 10cm × 10cm swatches, were pre-washed to remove industrial sizing. Three mordants were used: alum (potassium aluminium sulphate), lemon juice (acidic), and cocoa pod ash solution (alkaline). Mordanting followed three standard techniques across all samples: pre-mordanting (fabric treated in mordant solution overnight before dyeing), simultaneous mordanting (mordant and dye bath combined), and post-mordanting (fabric dyed first, then immersed in mordant). Each fabric swatch was dyed for 12 hours in 90ml dye extract, rinsed with distilled water, and air-dried at room temperature (Opoku-Asare et al., 2013).

3.5 Characterization and Fastness Analysis
UV-Vis spectroscopic analysis was conducted at the Central University Research Laboratory (CURL), Bowen University, Iwo, Nigeria, using a UV-Vis spectrophotometer measuring light absorbance from 200nm to 800nm. FTIR analysis was also performed at CURL using a Michelson Interferometer-based FTIR spectrometer to identify molecular bond vibrations and functional groups. Fastness testing (wash, light, and rubbing fastness) was conducted at the Federal University of Technology, Akure (FUTA), using a grey scale rating system from 1 (poor) to 5 (excellent), aligned with ISO standards (Tassew & Zenebesh, 2014; Muhammadu et al., 2017).

4. Results and Discussion
4.1 Spectroscopic Characterization: UV-Vis Analysis
UV-Vis analysis of all fifteen extracts revealed varied absorption profiles across the ultraviolet and visible regions (200–800nm), indicating diverse chromophoric systems. Key findings for selected samples are summarized in Table 3 below.

Neem leaf extract (Sample A) showed strong absorption at 227.5nm (3.753 AU) and 299nm (3.394 AU), characteristic of $\pi \rightarrow \pi^*$ and $n \rightarrow \pi^*$ electronic transitions typical of conjugated aromatic systems, consistent with the known tannin and flavonoid content of Azadirachta indica (Samanta & Agarwal, 2009). Hibiscus extract (Sample B) showed intense peaks at 308nm (3.777 AU) and 324nm (3.519 AU), corresponding to anthocyanin chromophores, consistent with its characteristic red-to-purple pigmentation under varying pH conditions (Cisse et al., 2012). Blood leaf (Sample C) demonstrated particularly broad absorption extending to 404.5nm (1.330 AU), suggesting polyphenolic and flavonoid structures. Neem bark (Sample I) showed the highest single absorbance value of 4.000 AU at 293nm, with visible-range absorption extending to 518nm, indicating highly conjugated chromophoric systems and a capacity for visible coloration.

The brimstone root (Sample L) exhibited the most extensive visible-range absorption, with strong bands at 305–361nm and detectable absorption as far as 798nm, consistent with the known dye properties of Morinda lucida, which is historically used as a red textile dye in West Africa (Burkill, 1985; Adetuyi et al., 2005). Onion peel (Sample N) showed a characteristic peak at 371nm (2.299 AU) attributable to quercetin, the dominant flavonoid in Allium cepa (Bechtold & Mussak, 2009).

Table 3: Summary of Key UV-Vis Absorption Data for Selected Plant Extracts

Sample	Plant Source	Major λmax (nm) / Abs (AU)	Chromophore Type	Likely Phytochemical
A	Neem Leaves	227.5 (3.753); 299 (3.394)	π→π*, n→π*	Tannins, Flavonoids, Polyphenols
B	Hibiscus	308 (3.777); 324 (3.519)	π→π*	Anthocyanins, Flavonoids
C	Blood Leaf	300.5 (3.865); 334 (3.848)	π→π*, n→π*	Polyphenols, Flavonoids
G	Cashew Bark	247 (3.883); 344 (3.706)	Extended conjugation	Tannins, Aromatic Compounds
I	Neem Bark	293 (4.000); 316 (1.941)	π→π* strong	Polyene, Highly Conj. Aromatics
L	Brimstone Root	342 (3.894); 361 (3.703)	Extended visible	Anthraquinones, Red Pigments
N	Onion Peels	371 (2.299)	Charge transfer	Quercetin, Flavonoids
O	Sorghum Sheaths	200 (2.975); 292 (2.078)	π→π* extended	3-Deoxyanthocyanidins, Apigeninidin

Source: CURL Laboratory Analysis, Bowen University, Iwo (2023)

4.2 FTIR Functional Group Analysis

FTIR analysis confirmed the presence of specific functional groups relevant to the dyeing properties of each extract. Across all fifteen samples, the most consistently identified bands were O–H stretching (3200–3570 cm^{-1}), indicative of hydroxyl-rich compounds including phenols, flavonoids, tannins, and carbohydrates; C=C stretching (1620–1680 cm^{-1}), characteristic of alkenyl and aromatic systems; and C–O stretching (1000–1055 cm^{-1}), associated with alcohols, phenols, glycosides, and polysaccharides.

Notable distinctions emerged between the three plant groups. Leaf extracts (Samples A–E) were generally dominated by O–H, C=C, and C–O bands, consistent with polyphenolic and flavonoid-rich profiles. Bark extracts (Samples F–J) showed more complex profiles: kapok bark (Sample F) yielded an unusual isothiocyanate band at 2012.8 cm^{-1} alongside imino compound signatures, while mango bark (Sample H) exhibited a cyanate/thiol band at 2016.5 cm^{-1} and Si–O–Si stretching at 1075.3 cm^{-1}, suggesting structural siloxane compounds. Root and sheath extracts showed distinctive signatures: brimstone root (Sample L) revealed isothiocyanate peaks at 2105.9 and 2037.0 cm^{-1} plus disulfide C–S stretching at 669.1 cm^{-1}, while sorghum sheaths (Sample O) confirmed imino and isothiocyanate compounds consistent with its 3-deoxyanthocyanidin-rich composition (Awika et al., 2004).

These FTIR findings are consistent with the existing literature on each plant. The O–H-rich profiles in neem and mango extracts align with their documented tannin content (Samanta & Agarwal, 2009); the anthocyanin profile of hibiscus is consistent with its known colorant chemistry (Da-Costa-Rocha et al., 2014); and the highly conjugated profile of brimstone root confirms the anthraquinone-related red dye compounds identified by Adetuyi et al. (2005) in Morinda lucida.

4.3 Fastness Properties of Dyed Fabrics

Fastness evaluation using grey scale ratings (1–5) across wash, light, dry rub, and wet rub parameters produced the following key findings (Table 4):

Table 4: Fastness Ratings Summary, Selected Dye Sources on Cotton and Silk

Dye Source	Mordant	Wash (C)	Wash (S)	Light (C)	Light (S)	Dry Rub (C)	Performance
Neem Bark	Alum	5	4	4	3	5	Excellent/Very Good
Henna Leaves	Alum	5	4	4	3	5	Excellent/Very Good
Sorghum Sheaths	Alum	5	4	4	3	5	Excellent/Very Good
Onion Peels	Alum	4–5	4	3–4	3	4	Very Good
Mango Bark	Alum	5	4	4–5	3–4	5	Excellent
Carrot Root	Alum	3–4	2–3	2	1–2	3	Fair–Good
Turmeric Root	Lemon	3	2	2	1–2	3	Good (limited light fast.)

C = Cotton; S = Silk. Ratings: 1 = Poor, 2 = Fair, 3 = Good, 4 = Very Good, 5 = Excellent. Source: Fastness testing conducted at FUTA (2023)

The data demonstrate that cotton consistently achieved higher fastness ratings than silk across all dye systems and mordants. This differential reflects the fundamental structural distinction between the two substrates: cotton's cellulose structure, rich in hydroxyl groups, enables stronger hydrogen bonding and chemical coordination with mordant-dye complexes, while silk's protein-based structure presents a more complex, less reactive interface under aqueous dyeing conditions (Broadbent, 2001; Samanta & Agarwal, 2009). These findings corroborate Mohammed (2015) and Shallendra et al. (2017).

Among mordants, alum and cocoa pod ash consistently outperformed lemon juice in fastness enhancement. Bark-derived dyes (neem bark, mango bark, cashew bark, guava bark, and kapok bark) demonstrated the highest absolute fastness ratings, attributable to their high tannin content, which facilitates robust coordination bonding with alum mordant and strong affinity for cellulosic fibres (Sayed et al., 2013; Cardon, 2007). Carotenoid-based dyes (carrot, turmeric) exhibited the lowest light fastness ratings, consistent with the known photolability of carotenoid chromophores (Shahid et al., 2013).

4.4 Shade Development and Mordanting Effects

Visual analysis of dyed fabrics across mordanting conditions revealed several systematic patterns consistent with established phytochemical principles (Table 5 summarizes representative outcomes).

Alum mordanting enhanced brightness and colour stability across virtually all plant sources, with the most notable effects on yellow-range chromophores such as turmeric (bright golden yellow on cotton), onion peels (deep golden orange), and mango leaves (creamy yellow). This is attributable to alum's capacity to form stable aluminium-dye coordination complexes that fix chromophores to fibre without substantially altering their colour wavelength.

Lemon juice (acidic mordant) consistently produced lighter, brighter, or warmer shades, particularly amplifying red-range pigments: hibiscus pre-mordanted with lemon yielded bright pink to red on silk, a result explicable by the pH sensitivity of anthocyanins, which intensify in acidic conditions (Bechtold & Mussak, 2009; Cisse et al., 2012). Cocoa pod ash (alkaline mordant) shifted chromophores toward darker, dull, or greenish tones—hibiscus post-mordanted with cocoa ash produced deep green on silk; blood leaf produced light blue to bluish-brown; and sorghum shifted from pinkish to burgundy/wine tones. These pH-induced bathochromic shifts are consistent with alkaline perturbation of electron delocalization in conjugated chromophoric systems.

Pre-mordanting was demonstrated as the most effective technique for achieving colour uniformity and depth, while simultaneous mordanting produced intermediate results. Post-mordanting, where dye binding precedes mordant application, produced the least uniform results, confirming the established principle that optimal mordant-fibre bonding must precede dye-fibre interaction for maximum fixation efficiency (Gulrajani, 2001; Shahid & Mohammad, 2013).

Table 5: Representative Shade Outcomes Under Different Mordanting Conditions (Selected Plant Sources)

Plant Source	Mordant	Technique	Cotton Shade	Silk Shade	Phytochemical Context	Reference
Hibiscus	Lemon	Pre	Pink	Bright Pink/Red	pH-sensitive anthocyanins	Bechtold & Mussak (2009)
Blood Leaf	Cocoa Ash	Pre	Light Blue	Bluish-Brown	Alkaline-induced bathochromic shift	Yusuf et al. (2017)
Turmeric Root	Alum	Pre	Light Golden Yellow	Golden Yellow	Curcumin + Al^{3+} complex	Samanta & Agarwal (2009)
Sorghum Sheaths	Cocoa Ash	Simultaneous	Wine	Light Wine	3-deoxyanthocyanidin; alkaline shift	Akogou et al. (2018)
Onion Peels	Alum	Pre	Deep Golden Orange	Yellowish Green	Quercetin–Al complex; protein fibre effect	Cardon (2007)
Guava Bark	Cocoa Ash	Simultaneous	Dark Brown	Light Brown	Tannin darkening under alkaline mordant	Samanta & Konar (2011)

Source: Author's studio experimentation and visual appraisal (2025)

5. Towards A Practice-Based Eco-Friendly Colouration Model For Nigeria

The integrated findings of this study, field procurement, aqueous extraction, mordanting optimization, spectroscopic characterization, and fastness evaluation, suggest the outlines of a replicable, practice-based model for sustainable textile dyeing in Nigeria. This model is grounded in two conceptual frameworks articulated in the thesis: the theory of material availability (Kalilu, 1991) and the concept of conservation as sustainable resource stewardship.

The theory of material availability posits that the accessibility and abundance of natural raw materials fundamentally shapes technological development and artistic production. Nigeria's tropical ecology provides exceptional material wealth: the fifteen plant species utilized in this study are all either cultivated or naturalized in the country's Southwest, and several, neem, mango, hibiscus/zobo, sorghum, and onion, are among the most widely available agricultural species in the region. The study demonstrates that these commonplace materials, when processed through standardized extraction and mordanting protocols, yield viable and aesthetically diverse dye systems at minimal cost.

The conservation framework underscores that sustainable development in the textile sector requires not merely the replacement of one input (synthetic dyes) with another (plant dyes), but a fundamental reorientation toward renewable resource cycles, waste minimization, and community-based production. Cocoa pod ash, a mordant used in this study, exemplifies this principle, being agricultural waste repurposed as a functional dye auxiliary, thereby supporting circular economy principles. Similarly, the sorghum sheaths used as dye source are typically discarded post-harvest, demonstrating value addition from waste materials.

Based on the study's findings, the practice-based model for eco-friendly colouration in Nigeria may be articulated across four interconnected stages:

Stage 1 – Indigenous Resource Identification and Sustainable Harvesting: Systematic documentation and mapping of dye-yielding plants in local ecological zones, with community-based protocols for sustainable harvesting and agronomic cultivation where appropriate.

Stage 2 – Standardized Aqueous Extraction: Optimization of extraction parameters (temperature 80°C, duration 1 hour, material-to-water ratio 30g/500ml) for each plant category, with protocols adapted for cottage industry and studio practice.

Stage 3 – Mordanting and Application: Selection of optimal mordant–technique combinations based on intended substrate (cotton vs. silk), desired shade, and fastness requirements. Alum pre-mordanting is recommended as a default for cotton; simultaneous cocoa ash mordanting for deeper tones; lemon for brightness enhancement in anthocyanin-rich dye systems.

Stage 4 – Scientific Validation and Quality Assurance: Integration of UV-Vis and FTIR characterization as quality assurance tools, enabling reproducibility monitoring and chromophore identification for commercial-scale production.

This model integrates traditional knowledge (indigenous plant use, mordanting traditions rooted in Yoruba and broader West African dyeing history) with contemporary scientific practice, creating a bridge between artisanal heritage and modern textile technology. Its implementation would support multiple aspects of sustainable development: job creation for farmers, dye processors, and textile artisans; reduction of dependence on imported synthetic dyes; revival of endangered indigenous dyeing knowledge; and contribution to the Sustainable Development Goals, particularly SDG 12 (Responsible Consumption and Production) and SDG 8 (Decent Work and Economic Growth).

6. Conclusion

This study has demonstrated that fifteen plant materials indigenous to Southwestern Nigeria collectively constitute a robust, scientifically validated dye palette capable of meeting the colour, fastness, and sustainability requirements of contemporary textile applications. Spectroscopic analysis confirmed the presence of diverse chromophoric systems—including flavonoids, tannins, anthocyanins, anthraquinones, and polyphenolic compounds—in all fifteen extracts, providing molecular evidence for the viability of these resources as dye sources. FTIR characterization documented specific functional groups responsible for dye-fibre interaction, while UV-Vis analysis identified absorption maxima corresponding to the observed colorations.

Fastness testing established that alum pre-mordanting on cotton substrates consistently yields the highest fastness ratings, particularly for bark-derived tannin-rich dyes (grades 4–5). Lemon mordanting enhances brightness in anthocyanin-based systems, while cocoa pod ash produces deeper, darker shades especially valued in traditional and artisanal aesthetics. The superiority of cotton over silk in dye absorption, and of pre-mordanting over simultaneous and post-mordanting techniques, were empirically confirmed.

The practice-based model proposed in this article offers a structured, scalable framework for transitioning Nigerian textile practice toward greater sustainability, environmental responsibility, and cultural authenticity. Future research should prioritize advanced chromatographic characterization (GC-MS), quantitative colorimetric measurement (CIELAB values), optimization of extraction parameters for individual plant species, investigation of combination-dye systems, and rigorous assessment of the economic and environmental benefits of natural dye adoption at the cottage industry and commercial scale.

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