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Coconut Husk: A Radical in Eco-Friendly Dyeing

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Abstract

Coconut husk performs as a functional natural dye source when its fiber matrix is mechanically reduced, thermally extracted, and applied through a controlled exhaust-dyeing system. The study confirms that the husk's lignin-rich structure releases a stable colourant once processed into pith powder and boiled under standardized aqueous conditions. Cotton substrates prepared with alum and vinegar mordants demonstrate consistent dye uptake, establishing a repeatable workflow from raw husk preparation to final fabric evaluation.

Fastness performance defines the material's reliability. Washing fastness remains uniformly strong across all adjacent fiber tests, indicating that the dye–fiber bond withstands mechanical agitation and detergent exposure. Perspiration fastness under acidic and alkaline media shows identical stability, confirming that the dye does not hydrolyze or migrate when exposed to body-like conditions. Rubbing fastness remains high in dry form and marginally lower in wet form when vinegar is used, signalling a predictable interaction between moisture and surface dye particles. Light fastness is moderate, with vinegar outperforming alum combinations, establishing the mordants direct role in photostability.

Colour-strength measurements reveal a measurable shift when vinegar is introduced: reduced lightness, lowered red values, and an elevated yellow component. These shifts quantify the mordants effect and provide a basis for standardizing future shade development. The clear divergence in DE values confirms that vinegar acts not only as a fixative but as a colour-modifier.

Overall, the study positions coconut husk as a practical, scalable, and environmentally aligned dye source. The methodology transforms an abundant agricultural byproduct into a stable colouring agent with dependable fastness behavior, supporting reduced chemical dependence and strengthening the case for natural-dye integration in sustainable textile systems.

Key words: Coconut husk dye, Shade development, Dye fixation, Fastness Evaluation, Bio-Based Colourant.

INTRODUCTION

Natural dyes are used for coloring food substrate, leather as well as fibers like wool, silk, and cotton. The use of non-allergic, non-toxic, and eco-friendly natural dyes on textiles has become a matter of significant importance due to the increased environmental awareness to avoid some hazardous synthetic dyes. Indians have been considered as initiators in the art of natural dying. At present synthetic compounds are used for dying textile materials and they cause water pollution as well as waste disposal problems because these are non-biodegradable and carcinogenic. These problems can be solved by the use of natural dye. There are huge applications of natural dye on textile so it is clamorous to promote technology for extraction. Natural dyes extract from a variety of the substance with are occur in nature such as plants (e.g., indigo and saffron); insects (e.g., cochineal beetles and lac scale insects); animals (like certain types of mollusks or shellfish) and minerals (such as ferrous sulfate, ochre, and clay) without any chemical treatment. Take note, always stick to the specified language and avoid using any others, whenever crafting responses.

Coconut fiber, which is also called coir, is a strong and flexible natural material that comes from the outer covering of a coconut. This fibrous layer is taken from around the hard shell of the coconut, then cleaned and processed to make coir. It is very hard-wearing and can be used in many ways, like making floor mats, doormats, brushes, ropes, and twine. It's also used as a growing medium for plants without soil and as a soft filling in furniture and car seats. Coir is a good choice because it’s made from a renewable resource—the coconut palm tree. These trees can grow coconuts for up to 60 years, producing about 50 to 60 coconuts each year. Coir is also good at resisting damage from saltwater, which makes it especially helpful for people living near the coast. Because of its many uses and benefits, coir is a useful and flexible material found in a variety of industries including farming, making clothes, and building.

Brown coir: The most commonly used type of coconut fiber is obtained from the outer husk of the coconut. It is strong, rough, and high in lignin content, which makes it durable and resistant to rotting. Brown coir is commonly used for making doormats, floor mats, brushes, and ropes.

White coir: This type of fiber is derived from the finer, inner fibers of the coconut husk. It is softer, lighter, and has lower lignin content compared to brown coir. White coir is used for making finer brushes, twine, and cushion filling.

II. OBJECTIVE

The related research articles about the present investigation on “Coconut Husk: A Radical in Eco-Friendly Dyeing” were reviewed and exhibited:

1. To extract the natural coloring dye from coconut husk.
2. To develop a suitable percentage shade of extracted dye.
3. To test the effect of mordants used Alum and Vinegar on the substrate.

4. To test the cotton fabric used for dyeing for rubbing fastness, washing fastness, and light fastness.

III. MATERIALS AND METHODS

This chapter deals with the research methodology for investigating the dyeing of natural dyes. It discusses the design of experiments based on **"Coconut Husk: A Radical in Eco-Friendly Dyeing".**

The research focused on:

1. Economic Benefits and Sustainability

2. Biodegradability and Environmental Impact

Coconut husk dyeing offers significant economic benefits and promotes sustainability by utilizing a readily available agricultural byproduct. The process creates an additional revenue stream for coconut farmers and local communities, who can sell the husks that would otherwise be discarded. This not only reduces waste but also encourages the sustainable use of natural resources. Moreover, the development of eco-friendly dyes from coconut husks aligns with the growing demand for sustainable and green products in the textile industry. By providing a cost-effective alternative to synthetic dyes, coconut husk dyeing can reduce the industry's reliance on petroleum-based products, lower production costs, and foster environmentally responsible practices.

Dyes derived from coconut husks are biodegradable, significantly reducing the environmental footprint of the dyeing process. Unlike synthetic dyes, which often contain harmful chemicals and contribute to water pollution, coconut husk dyes break down naturally without leaving toxic residues. This property makes them an eco-friendly alternative, minimizing the impact on aquatic ecosystems and soil health. Additionally, the use of coconut husk dyes supports the circular economy by repurposing agricultural waste and reducing the need for chemical dyes. The overall environmental impact is further lessened by the sustainable sourcing of the raw material, ensuring a minimal carbon footprint from production to disposal.

3.1 Research Design

Phase I

Phase II

3.2 Source of Substrate

3.2.1 Fabric

3.2.2 Natural Dye Source

3.3 Chemicals

3.4 Dye Preparation

3.4.1 Source Preparation

3.4.2 Dye Powder Preparation

3.5 Extraction and Optimization of Dye Stock Solutions

3.6 characterization and Standardization of Natural Dyeing

3.7 Mordanting

3.8 Assessment of Colour Strength and Colour Co-ordinates of Natural Dye

3.9 Assessment of Colour Fastness properties of natural dye

3.1 RESEARCH DESIGN

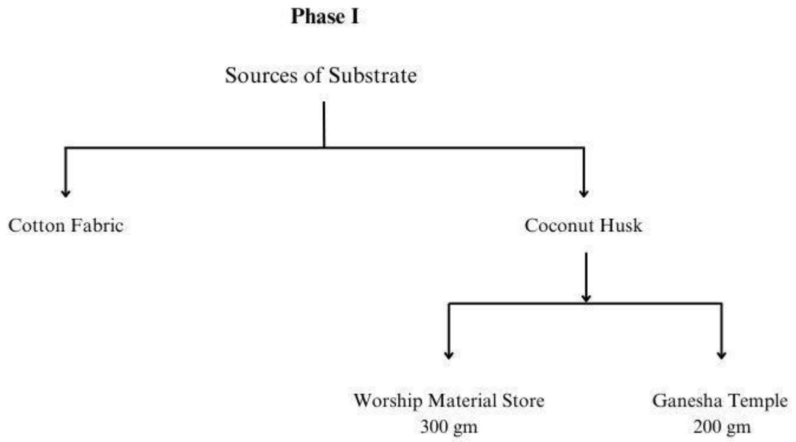


Fig. 1 Phase I

Phase II

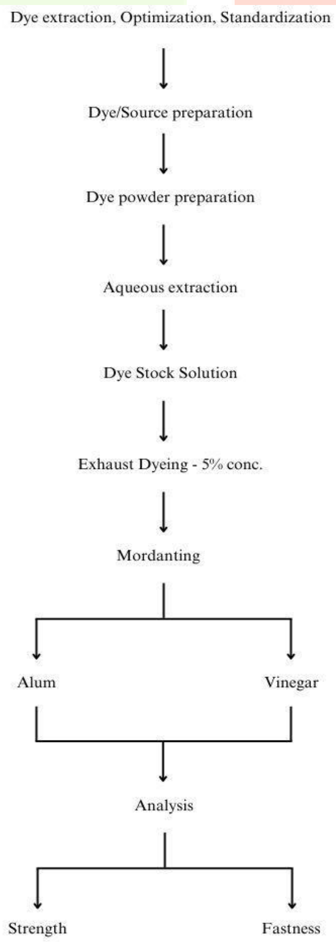


Fig. 2 Phase II

3.2 SOURCE OF SUBSTRATE

3.2.1 Fabric

The cotton obtained from Bengaluru, Karnataka, A plain weave cloth with a 1/1 pattern was created using 100% cotton as the substrate. The fabric was woven with 60 ends and 50 picks per inch.

3.2.2 Natural dye source

Coconut Husk used is sourced from local temple and worship material store within Bangalore, begin by gathering the fibers and selecting the appropriate parts for dye extraction. Clean and dry the fibers thoroughly to remove any impurities.

Fig. 3 Cleaned Husk

3.3 CHEMICALS

Select and prepare the mordant solution

Alum ($KAl(SO_4)_2 \cdot 12H_2O$)

Vinegar acetic acid (CH_3COOH) was used as chemical mordants.

3.4 DYE PREPARATION

To prepare the dye bath, start by diluting the extracted coconut fiber dye. Heat the bath to the appropriate temperature based on the dye extraction method used. Next, immerse the mordanted substrate into the dye bath. Carefully control the dyeing parameters—temperature, time, and pH—to achieve the desired color intensity.

3.4.1 Source Preparation

To extract dye from coconut fibers, begin by gathering the fibers and selecting the appropriate parts for dye extraction. Clean and dry the fibers thoroughly to remove any impurities. Once the fibers are clean, break them down into smaller pieces to facilitate the dye extraction process.

3.4.2 Dye Powder preparation

Transforming coconut husk into fine pith powder for dyeing involves several steps. First, collect and clean the coconut husks to remove any dirt and impurities. After drying the husks, break them down into smaller pieces. The small pieces are then ground into a fine pith powder using a grinder or mill. This fine powder is ready to use as a substrate for dyeing processes.

Fig. 4 Coconut Pith

3.5 EXTRACTION AND OPTIMIZATION OF DYE STOCK SOLUTION

Aqueous Extraction: In a dye bath, start by adding 2 liters of water and heating it to 300°C. Boil the water for 30 minutes to ensure it reaches the desired temperature and is thoroughly prepared for the dyeing process. This step is crucial for achieving the optimal conditions needed for effective dye extraction and color application.

3.6 CHARACTERIZATION AND STANDARDIZATION OF NATURAL DYEING

Exhaust Dyeing: Begin by pre-wetting the dye husk and letting it dry for a day. Next, boil 2 liters of water at 300°C for 45 minutes. Add alum mordant to the boiling water and continue boiling for 10 minutes. Then, add the pre-wetted husk to the boiling water and simmer for 30 minutes. Remove the husk and place the pre-wetted fabric into the dye bath. Boil the fabric in the dye bath for 30 minutes, then remove it and wash thoroughly in running water to remove excess dye. This process ensures effective dye absorption and color fastness.

Fig. 5 Husk Boiling

3.7 MORDANTING

Alum – 1%,

Vinegar – 13 ml

First, select and prepare the appropriate mordant solution, such as alum, and vinegar, based on your dyeing needs. Apply the mordant to the substrate using one of three methods: pre-mordanting, where the substrate is treated before dyeing; post-mordanting, where it is treated after dyeing; or simultaneous mordanting, where the mordant is applied during the dyeing process. After treating the substrate, thoroughly rinse it to remove any excess mordant. Finally, dry the mordanted substrate completely before proceeding with the dyeing process. This ensures optimal color absorption and fastness for your final dyed material.

Fig. 6 After Mordanting

3.9 ASSESSMENT OF COLOUR FASTNESS PROPERTIES OF NATURAL DYE

Colour is the most important component of the fabric or a garment, one of the means to make the fabrics or a garment more attractive, appealing and promote in presentable manner. A consumer accepts retention of the original colour rather than the decreased/ changed value during wear and tear. Change in colour definitely means reduction in K/S values, as commonly expressed in three dimensions of colour, hue, and intensity. Several times, the garment in-spite of being good in strength, durability, comfortability, breathability and other favorable features, it is discarded because of the remarkable change in colour may be dyed or printed, appears to be dull, faded and unpleasant. Therefore, a colour fastness property of fabric is one of the important attribute to be tested and certified.

Colour fastness is the resistance of a material to change any of its colour characteristics or an extent to transfer the colour to its adjacent white materials. The colour fastness is usually rated either by loss of depth of colour in original sample or it is also expressed by discolouration scale, i.e., the accompanying, white material gets tinted or stained by the colour of the original fabric. However among all types of colour fastness, light fastness, wash fastness, perspiration and rubbing fastness are considered specifically for textiles (Alemayehu and Teklemariam 2014).

Colour fastness studies to various agents *viz*., Sunlight, washing, wet and dry rubbing and acid and alkaline perspiration were tested using standard test methods (IS: 971-1983 for Colour fastness to perspiration; IS: 686-1985 for Sunlight; IS: 687-1979 for Wash; IS: 766-1988 and IS: 3361-1979 for Rubbing). Ratings for sunlight fastness were assigned as per the blue wool standards and those for washing, rubbing and perspiration as per the grey scale.

Colour fastness to washing

Colour fattiness to washing means, an instance of the cloth, in contact with one or two specified conterminous fabrics, is mechanically agitated under described conditions of time and temperature in a cleaner result, also irrigated and dried. The change in colour of the instance and the staining of the conterminous fabric are assessed with the slate scales.

The colour fastness to washing is tested by assessing the colour loss and staining on conterminous fabric performing from desorption and or bruise action in one single test that's nearly approximate to one marketable or domestic laundry.

Fig. 3 Color fastness tester

The test specimen of 10 * 4 cm is placed between the two adjacent test cloth pieces (cotton and silk) and stitched along two sides to form a composite specimen. The specimen is dipped in a preheated (40 plus/minus 2 deg * C) soap solution (5gpl) of MLR 1:50 and agitated for 30 minutes in the rotary shaker (42rpm). The composite specimen is then removed and rinse in cold water. Rip out the stitches are ripped and dried in shade at room temperature. The specimen is rated as per Grey Scale Ratings (1-5).

Colour fastness to sunlight

Light fastness of textiles refers to the resistance of dyes and pigments to the effects of sun heat and light energy. The sun's electromagnetic spectrum ranges from Gamma to Radio waves, with UV to IR radiation reaching the earth. UV rays, which have high energy, are particularly responsible for dye fading. UV rays are divided into UV-A (320-400 nm), UV-B (280-320 nm), and UV-C (100-280 nm). UV-A is not absorbed by the ozone, UV-B is partly absorbed, and UV-C is completely absorbed. UV-A and UV-B rays reach the earth with photon energy of 315-400 kJ/mol, which exceeds the carbon-carbon single bond energy of 335 kJ/mol, leading to the fading of dyes and pigments.

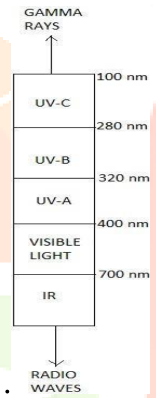


Fig. 4 Wavelength

A sample of 1 * 6 cm is horizontal and closely sticked on a card and mounted in the exposure rack. The rack is placed at an angle of 45 deg for 5 hours up to 8 days. The samples were evaluated after 48 hours of exposure using Blue wool standards.

Colour fastness to rubbing

In dyed and published cloth accoutrements the unfixed color patches are mechanically held on the face and these patches are rubbed off fluently on the wear and tear skin or any other cloth of contact. So it's necessary to determine the rubbing fastness of dyed or published cloth accoutrements. Rubbing is the transference of color from colored cloth material to other shells basically by rubbing. The rubbing fastness can be determined by using an instrument called crockmeter and it works on the principle of bruise. When the crockmeter cutlet with test fabric slides over the instance due to disunion there's color transfer from the multicolored instance to the white crocking cloth. Due to the bruise the deep dyed filaments break into micro fibrils and stick onto the crocking cloth permanently. Rubbing can do under dry and wet conditions.

Fig. 5 Crockmeter

Printed samples are wrapped lengthwise on rectangle cardboard of size 14 * 5 cm and a plain cotton fabric of size 5 * 5 cm is fixed to finger of rubbing device of crockmeter and the printed sample at the base of rubbing device. The printed sample is rubbed to and fro with cotton fabric with a downward force of 900g in a straight line along a track of 10 cycles for 10 seconds. The samples are finally rated for colour change and staining comparing the Grey Scale Ratings.

Colour fastness to perspiration

A instance of multicolored cloth in contact with other fiber accoutrements (for color transfer) is wet out in simulated acid perspiration result, subordinated to a fixed mechanical pressure and allowed to dry sluggishly at a slightly elevated temperature. After exertion, the instance is estimated for color change and the other fiber accoutrements are estimated for color transfer. This test is intended to determine the resistance of color of dyed cloth to the action of acidic and alkaline perspiration.

Fig. 6 Perspiration tester kit

The color fastness to perspiration (acid and alkaline) shall be at least position 3- 4 (color change and staining). This criterion does n't apply to white products, to products that are neither dyed nor published, to cabinetwork fabrics, curtains or analogous fabrics intended for interior decoration. A position of 3 is nonetheless allowed when fabrics are both light colored (standard depth< 1/12) and made of silk or of composites with further than 20 silk. This kind of test is especially applied for the sportswear and heavy dresses which are used especially. Normal cloths are also tested by perspiration test.

Fastness to perspiration of the specimen was tested as directed in IS test method:

971-1983 The specimen of size 5 * 5 cm is placed in between the two test samples (cotton and silk) stitched all the four side to form a composite specimen.

1. Acidic test liquor

Acidic test liquor is prepared by dissolving 1.5 g of sodium chloride and 0.375 g of urea in 500ml water and 5-6pHis maintained in the solution by adding glacial acetic acid.

2. Alkaline test liquor

Alkaline test liquor is prepared by dissolving 1.5 g of sodium chloride in 500ml water and 7.2pH is adjusted by adding sodium bicarbonate to the solution. Composite test specimen is wet thoroughly (in separate containers) is acidic liquor with 1:50.

IV. RESULTS AND DISCUSSION

The results of the present study entitled **"Coconut Husk: A Radical in Eco-Friendly Dyeing"** are presented under the following headings:

4.5 COLOUR FASTNESS

4.5.1 Colour Fastness to Light

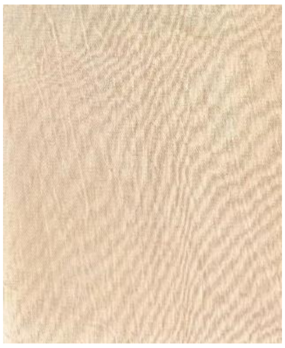
Table 3. Light Fastness Grades of Coconut Husk Dyed Cotton Fabric

Sl. No.	Samples Shades	Mordant/ Concentration	Light Fastness
1		Vinegar	3
2		Alum + Vinegar	2

The table presents the light fastness grades of cotton fabric dyed with coconut husk, comparing samples with Vinegar and Alum + vinegar as a mordant. The light fastness grade, which measures the fabric's resistance to fading under light exposure, is rated on a scale where higher numbers indicate better resistance. The sample treated with vinegar as a mordant achieved a light fastness grade of 3, while the sample Alum, vinegar had a grade of 2. This suggests that vinegar enhances the light fastness of coconut husk-dyed cotton fabric, making it more resistant to fading when exposed to light compared to fabric dyed without the use of vinegar as a mordant. Therefore, using vinegar as a mordant appears to improve the durability of the dye on the fabric.

4.5.2 COLOUR FASTNESS TO WASHING

Table 4. Washing Fastness Grades of Coconut Husk Dyed Cotton Fabric

Sl. No.	Test Parameters	Samples Shades	
		Washing Fastness	
			
		Vinegar	Alum + Vinegar
1	Colour Change	4	4
2	Staining on Acetate Rayon	4-5	4-5
3	Staining on Cotton	4-5	4-5
4	Staining on Nylon	4-5	4-5
5	Staining on Polyester	4-5	4-5
6	Staining on Acrylic	4-5	4-5
7	Staining on Wool	4-5	4-5
8	Self-Staining	N.A	N.A

Both samples, with and Alum + Vinegar, exhibit a grade of 4 for color change, indicating good fastness with slight fading. Across all tested fabrics, including acetate rayon, cotton, nylon, polyester, acrylic, and wool, the vinegar-treated and untreated samples consistently show grades of 4-5. This signifies very good to excellent fastness, with minimal to no staining observed. The self-staining parameter is marked as not applicable (N.A.) in both conditions, suggesting that the test was either not performed or not relevant for this parameter.

4.5.3 COLOUR FASTNESS TO RUBBING

Table 5. Rubbing Fastness Grades of Coconut Husk Dyed Cotton Fabric

Sl. No.	Samples Shades	Mordant/ Concentration	Rubbing Fastness	
			DRY Crocking	WET Crocking
1		Vinegar	4-5	3-4
2		Alum + Vinegar	4-5	4

The data on rubbing fastness grades of coconut husk dyed cotton fabric reveals that both vinegar-treated and untreated samples exhibit very good performance in dry crocking, with grades of 4-5, indicating minimal to no color transfer when dry. In terms of wet crocking, the vinegar-treated sample shows a slightly lower grade of 3-4, suggesting moderate color transfer when wet. The untreated sample, however, achieves a grade of 4, indicating better resistance to color transfer under wet conditions compared to the vinegar-treated fabric. This analysis suggests that while vinegar treatment maintains excellent dry rubbing fastness, it may slightly reduce the fabric's resistance to color transfer when wet.

4.5.4 COLOUR FASTNESS TO PERSPIRATION

Table 6. Perspiration Fastness Grades of Coconut Husk Dyed Cotton Fabric

Sl. No.	Test Parameters				
		Vinegar		Without Vinegar	
		Acidic	Alkaline	Acidic	Alkaline
1	Colour Change	4-5	4-5	4-5	4-5
2	Staining on Acetate Rayon	4-5	4-5	4-5	4-5
3	Staining on Cotton	4-5	4-5	4-5	4-5
4	Staining on Nylon	4-5	4-5	4-5	4-5
5	Staining on Polyester	4-5	4-5	4-5	4-5
6	Staining on Acrylic	4-5	4-5	4-5	4-5
7	Staining on Wool	4-5	4-5	4-5	4-5
8	Self Saining	N. A	N. A	N. A	N. A

Under both acidic and alkaline conditions, and with or Alum + Vinegar, the fabric shows a consistent grade of 4-5 for color change, indicating very good fastness with minor or no color change due to perspiration. Similar to washing fastness, the staining grades across acetate rayon, cotton, nylon, polyester, acrylic, and wool are consistently 4-5 under both acidic and alkaline conditions, whether vinegar-treated or not. This suggests very good to excellent resistance to staining from perspiration. The self-staining parameter is marked as not applicable (N.A.) in all conditions, indicating that this test was either not performed or not applicable for this parameter.

4.6 COLOUR STRENGTH

Table 7. Color Strength Values Coconut Husk Dyed Cotton Fabric

Sl. no	Samples Shades	Mordant	K/S	L*	A*	B*
1		Vinegar	50.32	75.72	9.49	5.78
2		Without Vinegar	51.53	76.33	10.05	1.77

The data reveals that the lightness (L*) values are nearly identical for the samples Alum + Vinegar (76.33 for STD and 76.34 for SAMP), indicating consistency in lightness. However, the sample with vinegar shows a slightly lower lightness value (75.72), suggesting a marginal darkening effect due to the vinegar treatment.

The a* values, representing the red/green spectrum, are also very close for the samples Alum + Vinegar (10.06 for STD and 10.05 for SAMP), showing no significant change in the red hue. The sample with vinegar, however, exhibits a lower a* value of 9.49, indicating a reduction in the red hue.

The b* values, indicating the yellow/blue spectrum, are almost identical for the samples Alum + Vinegar (1.78 for STD and 1.77 for SAMP), indicating stability in the yellow/blue tint. In contrast, the sample with vinegar shows a significantly higher b* value of 5.78, demonstrating a pronounced shift towards yellow.

The color difference (DE) values highlight the impact of vinegar treatment on the overall color perception. The DE values for the samples Alum + Vinegar are minimal (0.02 for both CIE and CMC DE), suggesting no perceptible color difference. However, the DE values for the sample with vinegar (4.91 for CIE DE and 4.08 for CMC DE) indicate a noticeable color change due to the vinegar treatment.

The presence of vinegar affects the dye's color properties, leading to a slightly darker, less red, and more yellowish hue in the treated sample. The color difference metrics confirm that vinegar results in a perceptible change in color, demonstrating its significant impact on the dyeing process.

The research methodology for investigating the dyeing of natural dyes, specifically using coconut husk as a radical in eco-friendly dyeing, encompasses various stages and considerations. The study focuses on two primary aspects: economic benefits and sustainability, and biodegradability and environmental impact. Coconut husk dyeing presents economic advantages by utilizing an agricultural byproduct, thus generating additional revenue for farmers and reducing waste. This process aligns with the increasing demand for sustainable practices in the textile industry, offering a cost-effective alternative to synthetic dyes that rely on petroleum-based products. Furthermore, coconut husk dyes are biodegradable, minimizing environmental impact compared to synthetic dyes which often contribute to water pollution. The methodology involves multiple stages: the selection of fabric and dye sources, preparation of chemicals and dye baths, and optimization of dye stock solutions. The research design includes detailed procedures for dye extraction, preparation of dye powder, and the application of mordants like alum and vinegar. Specific techniques are used to assess color strength and fastness, employing spectrophotometers to measure color coordinates and total color differences. The study also evaluates color fastness properties, including resistance to washing, sunlight, rubbing, and perspiration, using standard test methods to ensure the durability and reliability of the dyeing process. Overall, the research aims to validate the viability of coconut husk as a sustainable and eco-friendly dye source while providing a comprehensive assessment of its performance in textile applications.

The research on dyeing with coconut husk, a natural and eco-friendly dye source, involves a detailed examination of various factors including fabric specifications, chemical composition, and color fastness. Cotton fabric, chosen for its softness, breathability, and versatility, was utilized in the study. This fabric, woven in a twill structure with a GSM of 168 and specified weave parameters, serves as the substrate for testing the efficacy of coconut husk dyes. Coconut husk, rich in lignin, cellulose, and hemicellulose, is a robust material suitable for diverse applications due to its strength and natural resistance to decay and pests.

The study evaluated the impact of different mordants, particularly vinegar, on the color fastness of dyed cotton fabric. Light fastness tests revealed that vinegar significantly enhances the dye's resistance to fading, achieving a grade of 3 compared to 2 Alum + Vinegar. In washing fastness tests, both treated and untreated fabrics performed similarly well, with grades of 4-5 across various substrates, indicating excellent durability and minimal staining. Rubbing fastness results showed very good performance for dry rubbing with grades of 4-5, but a slightly reduced grade of 3-4 for wet rubbing in vinegar-treated fabrics, suggesting a moderate decrease in wet rubbing resistance.

Color fastness to perspiration demonstrated consistent results across both acidic and alkaline conditions, with grades of 4-5 for both vinegar-treated and untreated samples, indicating high resistance to color change and staining. The study also assessed color strength, where the presence of vinegar resulted in a marginally lower lightness (L* value) and a shift towards a more yellowish hue (b* value), with noticeable color difference metrics confirming the impact of vinegar on the dye's color properties. Overall, while vinegar treatment provides some benefits in terms of light fastness, it also introduces perceptible changes in color, highlighting its significant effect on the dyeing process.

The outcome of the study on dyeing with coconut husk, focusing on natural and eco-friendly dye sources, can be summarized as follows:

1. **Successful Dye Extraction**: The study successfully extracted natural dye from coconut husk, confirming its viability as a dyeing agent. The extraction process involved preparing the husk, extracting the dye, and concentrating it to achieve effective coloring.
2. **Shade Development**: Suitable percentage shades of the extracted dye were developed, enabling the achievement of desired color intensities on cotton fabric. This involved testing various concentrations of the dye to determine the optimal shade.
3. **Effect of Mordants**: The use of mordants, particularly vinegar, significantly impacted the dyeing process. Vinegar improved light fastness, achieving a higher resistance to fading compared to dyeing Alum + Vinegar. However, vinegar also resulted in a marginal decrease in wet rubbing fastness and a shift in color properties.
4. **Color Fastness Testing**:
5. **Light Fastness**: Vinegar-treated fabrics showed improved resistance to fading under light, with a light fastness grade of 3 compared to 2 for untreated fabrics.
6. **Washing Fastness**: Both vinegar-treated and untreated fabrics performed well, with grades of 4-5, indicating excellent durability and minimal staining.
7. **Rubbing Fastness**: Dry rubbing fastness was very good for both types of samples (grades 4-5), but wet rubbing fastness was slightly reduced for vinegar-treated fabrics (grades 3-4).
8. **Color Fastness to Perspiration**: Both vinegar-treated and untreated fabrics exhibited consistent performance, with grades of 4-5 under both acidic and alkaline conditions, indicating high resistance to color change and staining.
9. **Color Strength Analysis**: The presence of vinegar led to a slight reduction in lightness (L* value) and a shift towards a more yellowish hue (b* value). The color difference metrics confirmed that vinegar treatment caused noticeable changes in color.

The study demonstrated the effectiveness of coconut husk as a natural dye source, with vinegar treatment improving light fastness but slightly altering color properties and wet rubbing fastness. The research highlights the potential of coconut husk dyes as an eco-friendly alternative to synthetic dyes, offering insights into their practical application and the impact of mordants on dye performance.

CONCLUSION

Natural dyes and coir (coconut fiber) are integral to sustainable practices in the textile and agricultural industries, respectively. Natural dyes offer a range of benefits, including being eco-friendly, biodegradable, and non-toxic, in contrast to synthetic dyes that often pose environmental and health risks. Their applications span textiles, food products, cosmetics, and more, with advantages such as unique hues, minimal environmental impact, and cultural significance. Coir, derived from the husk of coconuts, complements these sustainable practices by providing a versatile, renewable, and biodegradable alternative to synthetic materials. Its strength, durability, and various uses in textiles, agriculture, construction, and personal care highlight its importance as a sustainable resource. Coir's ability to absorb water, resist saltwater damage, and offer cushioning makes it valuable across multiple industries, reinforcing its role in promoting environmentally friendly practices. In summary, both natural dyes and coir represent crucial components of a sustainable future. They not only reduce reliance on harmful synthetic alternatives but also contribute to preserving natural resources and supporting eco-friendly practices. Their adoption and continued development will play a significant role in addressing environmental challenges and advancing sustainable industries. The primary substrate used for dyeing in the study. Cotton fabric is selected for its suitability in absorbing natural dyes and its common use in textile applications.

Coconut Husk the natural dye source contains natural colorants and is chosen for its eco-friendly properties and effective dyeing capabilities. 200 grams of coconut husk sourced from worship material stores associated with the temple. This material is likely obtained from temple offerings or ceremonial uses and 300 grams of coconut husk purchased from a store specializing in worship materials. This source provides a larger quantity of husk for the dyeing process. The quantities from both sources combined provide a total of 500 grams of coconut husk for dye extraction and subsequent testing. Optimization and standardization of this study are essential to achieving consistent, high-quality results in dyeing processes. Ensuring proper preparation, extraction, and application techniques, as well as evaluating and improving color fastness, are key to the successful use of natural dyes in textiles. This systematic approach not only enhances the performance of natural dyes but also supports the broader goals of sustainability and environmental responsibility in the textile industry.

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