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Eco- Dyeing of Cotton and Silk with *Cocos nucifera* Husk Extract Using Bio-mordants

Narmathaa S and R. Sudhakar*
Department of Apparel Technology & Management, Bangalore University, Bangalore 560056, India

Abstract:
Background*: The growing demand for sustainable and eco-friendly textile practices has led to increased interest in natural dyes derived from agricultural waste. The present study was aimed at extracting natural dye from Cocos nucifera husk under optimized conditions and to dye cotton and silk at optimized conditions.*
Materials and Methods*: The dye was extracted from Cocos nucifera husk under optimized conditions using simple aqueous extraction method. Cotton and silk fabrics were dyed using a beaker dyeing machine at optimized conditions. The dyeing potential of coconut husk extract was evaluated using various bio-mordants such as pomegranate rind, areca nut, tamarind rind, tamarind seed coat, amla, and acacia bark applied at 5% on the weight of the material. The colour strength and CIE colour coordinates of the dyed samples were measured spectrophotometrically. The colour fastness properties of all the dyed samples were assessed using ISO standards.*
Results*: The mordant dyed samples showed improved color strength (K/S values) compared to unmordanted samples, with pomegranate rind and amla producing the deepest shades on silk, areca nut and tamarind rind performing best on cotton. The dyed fabrics were evaluated for light, washing, rubbing, and perspiration fastness, which showed moderate to good fastness properties.*
Conclusion: *Cocos nucifera husk is a promising natural dye source, offering a sustainable alternative to synthetic dyes and potential applications in organic textiles, handloom production, and eco-conscious fashion.*

Key Words*: Bio-mordants, coconut husk, Cocos nucifera, colour fastness, natural dye.*

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I. Introduction

The textile and clothing industry is one of the largest manufacturing sectors, encompassing the production of fibres, yarns, fabrics, and finished garments. It plays a vital role in the global economy, providing employment to millions and contributing significantly to GDP in many developing and developed countries[1]. Dyeing is one of the most critical steps in the textile process, providing materials with their colour and appearance[2]. Textile dyeing uses large volumes of water, and many synthetic dyes are only partially fixed to fabric, leaving the rest to be washed out as wastewater. The waste waters from dyeing units often contain toxic amines, heavy metals, and large amounts of salts, which can reduce oxygen in rivers, kill aquatic life, and contaminate drinking water supplies[2]. Dyeing is integral to the value chain, and innovations such as low-liquor-ratio processes, digital printing, and natural dyes are explored to improve efficiency and reduce environmental impact[3]. Natural dyes are derived from renewable sources such as plant leaves, bark, roots, fruits, or insect secretions and hence are biodegradable, generally non-toxic, and can often be applied without toxic chemicals[4]. Natural dyes not only produce soothing shades, but also impart functional properties like antioxidant, anti-inflammatory and anti-bacterial properties[5]. Pigments obtained from agricultural wastes that are otherwise considered waste are gaining popularity among the eco conscious dyers and consumers. By-products like onion skins, pomegranate peels, tea leaves, and banana stems are rich in tannins, flavonoids, and anthocyanins, all of which can create lasting colours on cotton, silk, and wool fabrics[6].

Large quantities of agricultural wastes like cereal straw, husks, and fruit and vegetable processing remains are generated yearly[7]. These leftovers provide an abundant and affordable source for extracting natural dyes. *Cocos nucifera* L is an important perennial crop cultivated in tropical countries around the world. *Cocos nucifera* husk, the byproduct of coconut processing industry is one such source where large quantities of husk are generated. Traditionally coconut husks were used for producing low-value coir, fuel, and growing media[8]. More recently the application of coir as reinforcing fibres in binder less fibreboards, construction materials, solid biofuels, natural fibre composites, and as an absorbent for heavy metals and toxic materials[9], development of eco-friendly paper and bioplastics from coconut husk fibres is reported[10].

Studies show that aqueous and alkaline coir pith and husk extractions yield brown to reddish pigments rich in polyphenols, which can dye cotton and silk with good wash and light fastness when combined with natural mordants[11]. Coir-based natural dyes not only colour fabrics but can also add antimicrobial, mild flame-retardant, fabric-strengthening, and UV-stabilising properties, mainly because of their high tannin, lignin, and polyphenol content. These multifunctional traits make coconut husk a valuable agricultural waste for sustainable, performance-enhanced textiles[6,12,13]. The presence of petunidin-3-glucoside, cyanidin-3-sambubioside, delphinidin-3-glucoside and proanthocyanidin trimer in *Cocos nucifera* husk makes it a valuable raw material for eco-friendly textile dyeing[17].

Many researchers and artisan dyers have turned to bio-mordants, or biopolymer-based materials that naturally contain compounds able to bond the dye to the fabric[15]. Bio-mordants are an environmentally friendly alternative to metal salts because they reduce toxic effluent while still giving good colour fastness[6]. Plants rich in tannins are the most common sources. Dried pomegranate rind, myrobalan fruits, oak or gall nuts, sumac leaves, and the bark of acacia or mangrove trees all supply tannins and phenolic acids that can form strong complexes with both the fibre and the colour molecules[16]. Though there are numerous references of tender coconut husk being utilized for dyeing with metal mordants, studies pertaining to the use of dry coconut husk and bio-mordants are sparse.

The present study aims to explore the potential of using readily available renewable byproduct, coconut husk as a source of natural dye for cotton and silk and to assess the effect of bio mordants namely, pomegranate rind (*Punica granatum*), areca nut (*Areca catechu*), tamarind rind, tamarind seed coat (*Tamarindus indica),* acacia bark (*Acacia catechu*) and amla (*Phyllanthus emblica*), on the dyeing properties.

II. Material and Methods

Material

Fabrics: Plain woven ready to dye cotton fabric (120g/m^2) and plain-woven degummed silk fabric (40g/m^2) was procured from a local store in Bangalore.

Chemicals: Laboratory grade sodium carbonate and acetic acid were used to adjust the pH during dyeing.

Dye source: The dried coconut husk in powder form collected locally was used for extraction of dye.

Bio-mordants: Dried rind of pomegranate (*Punica granatum*), nuts of areca nut (*Areca catechu*), rind and seed coat of tamarind (*Tamarindus indica*), bark of Acacia (*Acacia catechu*) and fruits of amla (*Phyllanthus emblica*) were used as source of bio-mordants.

Methods

Dye extraction: Dye extraction was carried out using known quantity of dry husk in water maintaining pH 7, 90℃ and 60 minutes. The obtained solution was filtered and used for dyeing.

Mordant extraction and mordanting: A known quantity of dried fruits of amla *(Phyllanthus emblica), rind of* pomegranate (*Punica granatum),* bark of acacia (*Acacia catechu*), nuts of areca nut (*Areca catechu),* rind and seed coat of tamarind (*Tamarindus indica*) were powdered separately and extracted in water maintaining pH 7, 90℃ for 60 minutes at liquor ratio 1:100, filtered and used for pre- mordanting at 5% (owf) at 90℃ for 30 minutes maintaining liquor ratio of 1:40.

Dyeing: Dyeing conditions for cotton and silk were optimized for colour strength separately by varying the dye bath pH, temperature, dye shade and duration with liquor ratio of 1:40. Dyeing was carried out in a beaker dyeing machine equipped with temperature control. The optimized conditions for dyeing cotton were pH 9, 90 ° C temperature, 60 minutes duration and 10% dye (owf). Silk dyeing was carried out by maintaining the bath pH at 5, 80℃ temperature, 60 minutes duration and 10% dye (owf). The dye shade % was based on the dry material (coconut husk). After dyeing the samples were subjected to soaping with 1% neutral soap for 15 min at 50℃ and then rinsed and dried. The liquor ratio maintained in both the cases was 1:40.

Determination of colour strength, colour coordinates and colour difference: The colour strength (K/S) of the dyed cotton and silk fabrics were determined using Kubelka Munk equation by measuring the surface reflectance of dyed samples using a spectrophotometer (Data color). Measurements were made for each treatment in triplicate over a wavelength range of 400– 700nm. The CIE L a* b* C h co-ordinates, 'L' corresponding to the lightness (100=White, 0=Black), a* corresponding to the red-green co-ordinate (positive sign=red, negatives sign=green) and b* corresponding to the yellow-blue co-ordinate (positive sign=yellow, negative sign =blue). 'C' is a measure of chroma (saturation) and represents the distance from the neutral axis, 'h' is a measure of hue and is represented as an angle ranging from 0 degrees to 360 degrees. Angles that range from 0 to 90 degrees are reds, orange and

yellow; 90 to 180 degrees are yellow, yellow-green and greens. 180 to 270 degrees are greens, cyan and blue 270 to 360 degrees are blue, purples, magentas and return to reds.

$K/S=(1-R)^2/2R$, where K is the absorption coefficient, S is the scattering coefficient and R is the reflectance at λmax.

Colour difference (ΔE) of the dyed samples between the unmordanted and mordanted samples was calculated using the formula, $\Delta E=\sqrt{(\Delta L)^2+(\Delta a)^2+(\Delta b)^2}$

where ΔL, Δa and Δb are the differences in L, a^* and b^* values respectively between mordant dyed and unmordanted dyed fabric samples.

Assessment of colour fastness properties: Colour fastness of all the dyed cotton and silk fabrics to light were determined as per ISO 105-B02[17], washing as per ISO 105 C02[18], perspiration as per ISO 105 E04[19], and rubbing as per ISO 105X12[20] methods.

III. Results and Discussion

Colour attributes of cotton and silk dyed fabrics: The colour strength, CIE colour co-ordinates and the colour difference values along with the images of the cotton fabrics dyed with the crude extract of *Cocos nucifera* husk is presented in Table 1.

Table 1. Colour strength, colour co-ordinates and colour difference of cotton samples dyed with *Cocos nucifera* husk extract

Mordant	K/S	L	a*	b*	C	h	ΔE	Sample image
Nil	1.72	68.31	12.02	14.89	19.14	51.10	-	
Pomegranate rind	2.97	70.64	10.43	14.29	17.69	53.88	1.9	
Areca nut	3.90	64.36	13.26	13.67	19.05	45.86	3.1	
Tamarind rind	3.79	70.55	11.00	9.86	14.77	41.85	5.1	
Acacia bark	3.12	62.48	15.07	14.09	20.64	43.08	5.0	
Amla	1.50	72.77	7.89	14.57	16.57	61.54	5.6	
Tamarind seed coat	1.51	69.47	11.42	15.80	19.49	54.14	1.8	

The dyed sample without the mordant recorded a K/S value of 1.72 with a* and b* value of 12.02 and 14.89 respectively indicating the sample to be in the red and yellow quadrant of the colour space diagram. The mordant dyed samples viz. pomegranate rind, arecanut, acacia bark and tamarind rind enhanced the colour strength, the maximum colour difference being recorded in case of tamarind rind followed by acacia bark, areca nut and pomegranate rind while the amla and tamarind seed coat mordanted samples showed a lowered K/S value. The polyphenols and tannins present in these bio-mordants have added to the colour of the samples besides also enhancing the uptake of the dye[16]. Amla adds almost no background pigment of its own, while an un-optimized tamarind seed coat bath lacks the depth. The use of these mordants have resulted in varied shades as reflected by the change in a*, b* values and the hue values. The Lightness values of the dyed samples also ranged from 62.48 to 72.77 indicating the influence of components present in the bio-mordants.

The colour strength, colour co-ordinates and the colour difference values of the silk fabrics dyed with the crude extract of *Cocos nucifera* husk is presented in Table 2. Pre-mordanting with bio mordants enhanced the colour values in all the cases except tamarind rind mordanted sample. Maximum increase was observed in pomegranate rind and amla mordanted samples. The presence of ascorbic acid and gallic acid in amla creates a powerful electrostatic attraction that pulls the anionic tannins and polyphenols of amla deep into the silk fibre core resulting in deeper shade as opposed to lighter shades on cotton. The colour difference observed was also maximum in acacia bark mordanted sample followed by areca nut. As these materials aggressively deposit their own intense, dark base pigments into the silk before actual dyeing, the colour difference value as compared to unmordanted

dyed silk sample is amplified significantly. The mordants have resulted in varying shades as reflected in the colour coordinates and the dyed images presented. As compared to cotton, silk samples appeared to be darker with better K/S values and a comparatively lower lightness value.

Table 2. Colour strength, colour co-ordinates and colour difference of silk samples dyed with *Cocos nucifera* husk extract

Mordant	K/S	L	a*	b*	C	h	ΔE	Sample image
Nil	2.79	67.30	8.52	17.73	19.67	64.32	-	
Pomegranate rind	4.30	63.79	9.67	19.33	21.61	63.42	1.8	
Areca nut	2.99	63.30	10.96	18.23	21.28	58.99	3.3	
Tamarind rind	2.57	68.24	8.33	16.77	18.72	63.57	0.7	
Acacia bark	3.19	61.59	12.96	20.33	24.11	57.49	5.1	
Amla	4.14	64.03	8.78	18.07	20.09	64.08	1.3	
Tamarind seed coat	2.92	64.51	10.81	18.39	21.33	59.54	2.8	

Colour fastness properties of dyed cotton: The dyed samples were assessed for colour fastness properties with respect to light, washing, perspiration and rubbing as the end use application of any dyed textile material depends on the resistance these materials offer to change in colour or staining when exposed to washing, day light, rubbing and human perspiration. The colour fastness properties of *Cocos nucifera* husk extract dyed cotton fabrics are presented in table 3. The unmordanted dyed cotton fabric showed a light fastness grade of 3 which improved to 3-4 to 4 on mordanting, while washing fastness also improved from 3 to 4 on mordanting with respect to change in colour and 4-5 from 3-4 in case of staining. Perspiration fastness (acidic) was found to be good even without mordanting while it showed an improvement on mordanting in case of alkaline perspiration from 3 to 4-5. The rubbing fastness also showed an improvement from 3-4 to 4-5 (dry) and 3 to 4 (wet) on mordanting. Overall, the fastness properties of all the dyed samples were found to be satisfactory.

Table 3. Colour fastness properties of cotton fabrics dyed with *Cocos nucifera* husk extract.

Mordant	Light	Washing		Perspiration (acid)		Perspiration (alkali)		Rubbing	
		Cc	Cs	Cc	Cs	Cc	Cs	Dry	Wet
Nil	3	3	3-4	4-5	3-4	3	3	3-4	3
Pomegranate rind	3-4	4	4-5	4-5	4	4-5	4-5	4-5	4
Areca nut	3-4	4	4-5	4-5	4-5	4	4-5	4-5	4
Tamarind rind	3	4	4-5	5	4-5	3-4	4-5	4-5	4
Acacia bark	4	4	4-5	4-5	4-5	3-4	4-5	4-5	4
Amla	3-4	4	4-5	4-5	4	4	4-5	4-5	4
Tamarind seed coat	3-4	4	4-5	4-5	4	4	4	4-5	4

Colour fastness properties of dyed silk: The unmordanted silk fabrics showed a light fastness grade of 3, which improved to 3-4 and 4 on mordanting, while washing fastness, perspiration fastness and rubbing fastness of the unmordanted samples were fair to good (table 4). All the dyed samples showed improvement in fastness properties on mordanting. The proanthocyanidin trimer present in the extract acts as a natural tannin which helps the pigments bind to natural fibres improving colourfastness against washing and light[14].

Table 4. Colour fastness properties of silk fabrics dyed with *Cocos nucifera* husk extract.

Mordant	Light	Washing		Perspiration (acid)		Perspiration (alkali)		Rubbing	
		Cc	Cs	Cc	Cs	Cc	Cs	Dry	Wet
Nil	3	4	4	3-5	3	3	3	3-5	3
Pomegranate rind	4	4-5	4-5	4-5	4-5	4	4-5	4-5	4-5
Areca nut	3-4	4	4-5	4-5	4-5	4-5	4-5	4-5	4-5
Tamarind rind	4	4	4-5	4-5	4-5	4	4-5	4-5	4
Acacia bark	3-4	4	4-5	4-5	4-5	4	4-5	4-5	4
Amla	3-4	4	4-5	4-5	4-5	4	4-5	4-5	4-5
Tamarind seed coat	3	4	4-5	4-5	4-5	4	4-5	4-5	4-5

IV. Conclusion

The present study demonstrates that *Cocos nucifera* husk extract can be successfully used for dyeing cotton and silk. Use of bio mordants resulted in improved colour strength and colour fastness, exhibiting good fastness to washing, rubbing, perspiration and satisfactory fastness to light besides resulting in various shades. As the dye extraction and the process of dyeing involves simple procedures and does not involve the use of harmful chemicals the entire process is eco-friendly. Hence, the abundantly available husk of *Cocos nucifera* in cultivating nations offers a significant scope for the sustainable valorisation of this agricultural waste into a potential renewable source of natural dye for both cotton and silk.

References

[1]. Bick, R., Halsey, E., & Ekenga, C. C. The global environmental injustice of fast fashion. Environmental Health, (2018) 17(1), 92
[2]. Holkar, C. R., Jadhav, A. J., Pinjari, D. V., Mahamuni, N. M., & Pandit, A. B. A critical review on textile wastewater treatments: possible approaches. Journal of environmental management, (2016). 182, 351-366.
[3]. Shen, L., Worrell, E., & Patel, M. K. Environmental impact assessment of man-made cellulose fibres. Resources, Conservation and Recycling, (2010) 55(2), 260–274.
[4]. Gulrajani, M. L. Present status of natural dyes. Indian Journal of Fibre and Textile Research, (2001) 26(1/2), 191-201.
[5]. Mazeyar, P. An environmentally method for dyeing rug pile using fruit waste colorant. Research Journal of Chemistry and Environment, (2009) 13(4), 49–53.
[6]. Samanta, A. K., & Agarwal, P. Application of natural dyes on textiles. Indian Journal of Fibre & Textile Research, (2009) 34(4), 384–399.
[7]. FAO. The state of food and agriculture 2021: Making agrifood systems more resilient to shocks and stresses (2021)
[8]. Atapattu, A. J., Udumann, S. S, Nuwarapaksha, T. D., & Dissanayaka, N. S. Upcycling coconut husk by-products: Transitioning from traditional applications to emerging high-value usages. In R. Neelancherry, B. Gao, & A. Wisniewski Jr (Eds.), Agricultural waste to value-added products(2024) 317–342. Springer. https://doi.org/10.1007/978-981-97-2535-9_12
[9]. Stelte, W., Reddy, N., Barsberg, S., & Sanadi, A. R. Coir from coconut processing waste as a raw material for applications beyond traditional uses. BioResources, (2023) 18(1), 2187–2212
[10]. Ozkan Karabacak, A., Sufer, O., & Pandiselvam, R. Coconut husk: A sustainable solution for eco-friendly packaging applications. Environment, Development and Sustainability, (2024) 26(12), 30379–30408. https://doi.org/10.1007/s10668-024-05154-8
[11]. Kashyap, R., Sharma, N., & Sharma, L. Dyeing of cotton with natural dye extract from coconut husk. International Journal of Science Technology & Engineering, (2016) 3(4), 92–95.
[12]. Rodiah, M. H., Nur Asma Fhadhila, Z., Kawasaki, N., Noor Asiah, H., & Aziah, M. Y. Antioxidant activity of natural pigment from husk of coconut. Pertanika Journal of Tropical Agricultural Science, (2018) 41(1), 441–451.
[13]. Kasim, K. F., Ghafar, N. A. A., & Kadir, N. A. Optimization of natural dye extraction from coconut husk. International Journal of Biomass Utilization and Sustainable Energy (IJBUSE), (2023) 1(1), 1–13.
[14]. Roslan, M. S., Zaini, N. A. M., & Awang, N. A. Extraction of natural dye from the mesocarp and exocarp of Cocos nucifera: Textile dyeing and colour fastness properties. Materials Today: Proceedings, (2021) 42(1), 198–203.
[15]. Prabhu, K. H., & Bhute, A. S. Plant based natural dyes and mordants: A review. Journal of Natural Products and Plant Resources, (2012) 2(6), 649–664.
[16]. Benli, H. Bio-mordants: a review. Environmental Science and Pollution Research, (2024) 31(14), 20714-20771. doi: 10.1007/s11356-024-32174-8

[17]. International Organization for Standardization. Textiles — Tests for colour fastness — Part C10: Colour fastness to washing with soap or soap and soda (ISO Standard No. 105-C10: 2006).
[18]. International Organization for Standardization. Textiles — Tests for colour fastness — Part E04: Colour fastness to perspiration (ISO Standard No. 105-E04: 2013).
[19]. International Organization for Standardization. Textiles — Tests for colour fastness — Part B02: Colour fastness to artificial light: Xenon arc fading lamp test (ISO Standard No. 105-B02: 2014).
[20]. International Organization for Standardization. Textiles — Tests for colour fastness — Part X12: Colour fastness to rubbing (ISO Standard No. 105-X12: 2016).