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Effects of Different Mordanting Techniques on Fabrics Dyed With Coconut Husk Dye and Colour Fastness Properties

Rodiah Mohd Hassan[1*], Noor Asiah Hassan[1], Norakma Mohd Nor[1], Norazlina Idris[1] and Nurhafizah Ibrahim[1]

[1]*Department of Science and Biotechnology, Faculty of Engineering and Life Sciences, Universiti Selangor, Bestari Jaya Campus, Jalan Timur Tambahan, 45600 Bestari Jaya, Selangor, Malaysia*
E-mail: *rodiah@unisel.edu.my*

Abstract. The dyeing potential of *Cocos nucifera* (coconut) husk extracted by microwave-assisted extraction was evaluated with three different mordanting methods: pre-mordanting, meta-mordanting, and post-mordanting. Natural dye from coconut husk powder was extracted separately using 0.8 M sodium carbonate (Na_2CO_3) and 0.8 M sodium hydroxide (NaOH) solution. The dyeing and mordanting procedure were carried out with 12% tannic acid as biomordant. This study explores the effect of different mordanting techniques on three fabrics, cotton, crepe, and lycra, when dyed with the natural dyes of coconut husk. The purpose is to investigate the effects of different mordanting techniques on colour fastness (fastness to wash, rub, and perspiration). A comparison of the three mordanting techniques showed that the meta-mordanting method gave the highest depth of shade and colour values on cotton, crepe, and lycra. Meanwhile, the colour strength values are higher on fabrics with the Na_2CO_3 dye. The colour strength for all fabrics dyed with the Na_2CO_3 dye follows the order: meta-mordanting > post-mordanting > pre-mordanting. Of the three fabrics studied, lycra gave the deepest shades, as well as superior wash and perspiration fastness. The resulting wash and perspiration fastnesses of the dyed lycra fabrics are good to excellent.

Keywords: Coconut, dyeability, natural colourant, and shade

1. Introduction

Since prehistoric times, natural dyes have been used to colour food substrates, leather, and natural protein fibres such as wool, silk, and cotton. Due to increasing environmental awareness, the use of non-allergic, non-toxic, and eco-friendly natural dyes on textiles has become important to avoid some hazardous synthetic colours (Samanta & Agarwal, 2009). Natural dyes, which are biodegradable and compatible with the environment, have gained popularity worldwide (Gumrukcu et al., 2008). Natural dyes are an interesting class of colourants due to the possibility of generating the dyeing materials from natural renewable sources (Bechtold et al., 2003).

Mordanting is the process of treating the textile fabric with metallic salts or other complex-forming agents that bind natural mordantable dyes to the textile fibres. Mordanting can be accomplished by pre-mordanting, meta-mordanting, and post-mordanting. Various types and selective mordants, as well as their combinations, can be used on textile fabrics to achieve variable colour/shade, accelerate dye uptake, and improve the colour fastness behaviour of any natural dye (Samanta & Agarwal, 2009). The mordant and mordanting process often directly impacts the colour shades and fastness characteristics produced. Because outcomes vary based on plant and mordant type, it is impossible to offer specific guidelines and instructions for mordanting methods. Depending on the plant and mordant type, pre- and post-mordanting may result in darker shades (Işmal, 2016).

Mordant is commonly used with natural dyes because it aids dye take-up and promotes colour fastness. Aluminium potassium sulphate ($KAI(SO_4)_2.12H_2O_2$), ferrous sulphate ($FeSO_4.7H_2O$), and copper sulphate ($CuSO_4.5H_2O$) are the most commonly used metal mordants in natural dye (Ramli et al., 2021). The replacement of metal mordants with biomordants is an innovative and popular field of research and is fast gaining popularity.

Numerous plants and biomaterials might be suitable mordants for dye fixation and colour gamut expansion in textiles. Their mordant and fixing power can differ based on their chemical composition, tannin, and metal ion content (Işmal & Yildrim, 2019). Tannic acid, tannin, tartaric acid, and metal-containing plants are examples of biomordants. They are acclaimed bio- and eco-friendly alternatives to metal mordants, with acceptable dyeing and fastness qualities. Biomordants in this context include tannin, tannic acid, tartaric acid, metal-containing plants, biowastes, and by-products (Işmal & Yildrim, 2019). Mordant concentration is particularly important for darkness in textile (Işmal, 2016).

The coconut husk (*Cocos nucifera*) has been considered a rich source of natural dye (Rodiah et al., 2018). The feasibility of *C. nucifera* dye husk as a natural dye for dyeing cotton, crepe, and lycra fabric via colour measurement and the colour rating was investigated in this study. In this research, the effects of three mordanting techniques, i.e., pre-mordanting, meta-mordanting, and post-mordanting with tannic acid as biomordants, were compared by observing colour diffusion and dyeing of the fabrics.

2. Materials and methods

2.1 Sample Preparation

The coconut husk (*C. nucifera*) was obtained from a coconut plantation in Tanjung Karang, Selangor, Malaysia. Mesocarps of matured brown coconut were separated from the exocarps before being sliced into little pieces (2–3 cm). The mesocarps were then processed into powder using a grinder machine and stored in a zipper bag. The samples were kept away from heat and humidity prior to the experiment to avoid contamination (Hassan et al., 2015).

2.2 Preparation of Dye Extraction

In a conical flask, 10 g of *C. nucifera* powder was mixed and agitated with 200 mL of 0.8 M sodium carbonate (Na_2CO_3). To extract the dye, the mixture was heated in a microwave oven at 300 W for 4 min. The heated samples were cooled before being strained using a tea strainer and filtered with filter paper (150 mm; CHM, Germany) to remove plant debris. The filtrate was identified as Na_2CO_3 dye extract. The filtrate was stored at 4 °C in the dark before analysis. The natural dye extract was prepared with similar methods using 0.8 M sodium hydroxide (NaOH). The extract obtained was known as NaOH dye extract (Rodiah et al., 2022). All samples were prepared in triplicate.

2.3 Mordanting and Dyeing Processes

Three different mordanting methods were employed, i.e., pre-mordanting, meta-mordanting, and post-mordanting using 12% tannic acid as the biomordant. In the pre-mordanting method, the fabric was impregnated in a mordanting solution at a liquor ratio of 1:20 at 60 °C for 60 min before proceeding to the dye bath at a liquor ratio of 1:20 at 80 °C for 60 min. In the post-mordanting method, the fabric was impregnated in a dye bath at a liquor ratio of 1:20 at 80 °C for 60 min. After dyeing, the dyed fabric was soaked in 200 mL of 12% tannic acid solution at 60 °C for 60 min. Meanwhile, in meta-mordanting, the mordant was added to the dye bath before dyeing. The fabric was dyed at a liquor ratio of 1:20 at 80 °C for 60 min. The dyed fabrics in all mordanting methods were rinsed with tap water, squeezed, air-dried at room temperature, and kept ready for colour coordinate and fastness test. Three distinct fabric types, i.e., cotton, crepe, and lycra, were used for the mordanting and dyeing technique as previously described. Each fabric was cut in triplicate to a specific size of 4 × 4 cm before dyeing and mordanting.

2.4 Colour Assessment and Scoring

A colour reader (Konika Minolta, Japan) was used to measure the L*, a*, b*, c*, and h* values. L* measures the lightness/darkness of fabric, a* measures the fabric's redness/greenness, with positive values indicating red and negative values indicating green, and b* measures the fabric's yellowness/blueness, with positive values indicating yellow and negative values blue. Meanwhile, c* denotes the chroma, which measures the strength of the colourant, and h* represents the hue. The deeper the colours, the larger the intensity of the a* and b* values. This study used the rate for colour changes based on ISO 105-C02:1989.

2.5 Fastness Test

The dyed samples were assessed for fastness characteristics using the American Association of Textile Chemists and Colourists (AATCC) Test Method 61 (2009). Colour fastness to washing was carried out according to ISO 105-C02:1989. The assessment of colour changes was observed on a scale of 1 (very poor) to 5 (excellent). Colour fastness to rubbing (dry and wet) was assessed as per IS: 766-1984 method using a manually operated crock meter, and the rate for colour changes was recorded on a scale of 1 (extremely staining) to 5 (no staining). Colour fastness to perspiration was evaluated using an IS 9711983 composite specimen, which was created by placing the two test samples between two adjacent pieces of fabric and stitching all four sides. The sample was individually soaked in the test solution (acidic/alkaline) for 30 min at room temperature. The sample was placed between two glass plates under a 4.5 kg load (10 lbs). The apparatus was kept in the oven for 4 hours at 37 °C. Then, the test sample was removed and air-dried. The assessment for colour changes was recorded on a scale of 1 (very poor) to 5 (excellent).

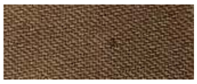
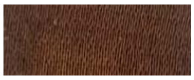
3. Results and Discussion

3.1 Dyeing Outcomes

Colour coordinates are significant in the appearance of dyed fabrics, as observed from the tonal variances between fabrics. Tables 1 and 2 demonstrated that the L values for all fabrics dyed with NaOH dye extracts are slightly higher than the Na_2CO_3 dye extracts. It could be due to weak bonding between the dye molecule in NaOH dye extracts and the fibre. The L* values are low when in the meta-mordanting technique, indicating an increase in the depth of shade. In this study, the lower L* value indicates the deeper the shade of the fabric. When comparing the three mordanting procedures used for dyeing cotton, crepe, and lycra, the meta-mordanting technique produced a greater depth of shade and colour values than the other two methods. This could be due to the tannic acid-enhanced capacity that forms complexes with the dye molecules in the technique. Coconut husk dye provides excellent substantivity for all fabrics, especially lycra. The shades obtained from all post-mordanted dyed fabrics showed a moderate shade than pre-mordanted dyed fabrics.

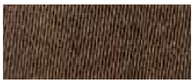
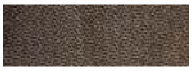
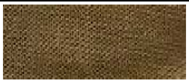
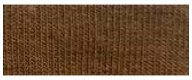
Meta-mordanted fabrics dyed with NaOH and Na_2CO_3 dye extracts produced a dark brown colour, indicated by a combination of a slightly lower L* value and a more positive a* value (a*: 4.57–13.26). The L*, a*, and b* results show that the Na_2CO_3 dye extract had more affinity for lycra than cotton and crepe when meta-mordanted with tannic acid. The values of b* > a* and both positive in all meta-mordanted dyed fabrics, indicating that their colour appearance is closer to yellow than red. Data in Tables 1 and 2 shows that lycra is the best fabric for dyeing than cotton and crepe. The suitability of the fabrics dyed with NaOH and Na_2CO_3 dye extracts is observed in the following order: lycra > crepe > cotton. In this study, the lycra used was made of a combination of polyester and polyurethane (a flexible plastic material). The obtained results agree with the findings by Saxena and Raja (2014), who reported that textile fibres, particularly cellulosic, do not have a high affinity for the majority of natural dyes. Hence, they must go through a mordanting process. Unlike animal fibres, vegetable fibres such as linen and cotton do not readily absorb mordants, resulting in a duller colour than the vivid colours obtained with wool and silk. Cotton requires mordanting because it is more difficult to dye than wool or silk due to the lack of amino and carboxyl groups that provide attachment sites for dye molecules.

Table 1. Colour coordinates for fabrics dyed with 0.8 M Na_2CO_3 dye extracts

Types of Dye	Fabric	Mordanting Techniques	Colour Coordinates					Colour obtained
			L	a	b	C	H	
0.8 Na_2Co_3	Cotton	Pre-mordanting	57.20	8.30	18.63	20.40	65.90	
		Meta-mordanting	45.63	13.26	23.10	26.73	59.73	
		Post-mordanting	53.70	5.60	10.10	11.57	61.03	
	Crepe	Pre-mordanting	57.53	7.43	18.80	20.23	68.53	
		Meta-mordanting	37.83	12.1	16.5	20.46	53.4	
		Post-mordanting	50.30	5.50	10.20	11.63	61.93	
	Lycra	Pre-mordanting	47.87	9.97	25.57	27.43	68.67	
		Meta-mordanting	33.67	9.67	12.63	15.83	52.30	
		Post-mordanting	45.27	8.47	17.27	19.27	63.93	

Note: $NaCO_3$ = Sodium carbonate

Table 2. Colour coordinates for fabrics dyed with 0.8 M NaOH dye extracts

Types of Dye	Fabric	Mordanting Techniques	Colour Coordinates					Colour obtained
			L	a	b	C	H	
0.8 NaOH	Cotton	Pre-mordanting	64.97	4.57	14.83	15.60	72.87	
		Meta-mordanting	43.83	8.63	14.97	17.27	60.67	
		Post-mordanting	56.73	5.97	6.93	9.20	49.17	
	Crepe	Pre-mordanting	57.97	7.27	19.17	20.47	69.27	
		Meta-mordanting	41.80	7.53	13.00	15.03	59.87	
		Post-mordanting	51.43	5.77	7.10	9.13	50.97	
	Lycra	Pre-mordanting	62.43	5.40	25.50	26.07	78.07	
		Meta-mordanting	41.83	10.30	22.13	24.40	65.03	
		Post-mordanting	45.27	6.70	13.23	14.83	63.10	

Note: NaOH = sodium hydroxide

3.2 Colour Fastness Properties

Colour fastness is the resistance of a material to change its colour characteristics or the extent to which its colourants are transferred to neighbouring white materials in contact. Colour fastness is commonly described as losing colour depth in the original sample or a staining scale (Samanta & Agarwal, 2009). Tables 3 to 6 summarise the colour fastness evaluation to washing, rubbing, and perspiration of the fabrics dyed with NaOH and Na_2CO_3 extracts. All fabrics dyed with Na_2CO_3 and NaOH dye extracts showed reasonable colour fastness properties to washing, rubbing, and perspiration on cotton and crepe, but the fabrics dyed with NaOH dye extracts were generally non-fast to acid perspiration.

The wash fastness of dyed cotton, crepe, and lycra fabrics mordanted with different mordanting techniques is presented in Table 3. The wash fastness property ranged from good (3) to very good (4) when the meta-mordanting technique was applied regardless of the type of fabric. Colour changes in cotton, crepe, and lycra fabrics dyed with Na_2CO_3 dye extracts and pre-mordanted with tannic acid are excellent (5) to very good (4) but rated as good (3) when dyed with NaOH dye extracts using the pre-mordanting technique. Some dyes experience significant colour changes when washed due to trace amounts of alkali in the washing solutions (Samanta & Agarwal, 2009). However, in this research, both dye extracts are alkaline; hence, the detergent used during wash fastness did not affect the colour changes. The term “fastness to rubbing” refers to the ability of a fabric to not transfer its colour when rubbed against another layer of fabric or material. In the case of fastness to dry rubbing, higher rubbing fastness ratings (5) are observed for all fabrics dyed with NaOH and Na_2CO_3 dye extracts, irrespective of the mordanting technique (Table 4). However, fastness to wet rubbing indicated that all pre-mordanting techniques increased resistance of transfer of colour to test fabrics regardless of the type of fabric, with a rating score of 3 to 4 (slightly staining to negligible staining).

Tables 5 and 6 represent the perspiration fastness properties of fabrics (cotton, crepe, and lycra) dyed with NaOH and Na_2CO_3 extracts. All fabrics dyed with Na_2CO_3 dye extract showed good to very good (3 to 4) for all mordanting techniques in the acid perspiration fastness scores but ranged between very good and fair (4 to 2) when dyed with NaOH dye extract.

Table 3. Rating of colour fastness to washing

Types of Dye	Fabric	Mordanting Techniques	Colour rating (1-5)	
			Before wash	After wash
0.8 Na_2Co_3	Cotton	Pre-mordanting	5	4
		Meta-mordanting	5	3
		Post-mordanting	5	3
	Crepe	Pre-mordanting	5	4
		Meta-mordanting	5	3
		Post-mordanting	5	2
	Lycra	Pre-mordanting	5	5
		Meta-mordanting	5	3
		Post-mordanting	5	4
0.8 NaOH	Cotton	Pre-mordanting	5	2
		Meta-mordanting	5	4
		Post-mordanting	5	3
	Crepe	Pre-mordanting	5	2
		Meta-mordanting	5	4
		Post-mordanting	5	2
	Lycra	Pre-mordanting	5	2
		Meta-mordanting	5	4
		Post-mordanting	5	4

Note: Na_2CO_3= Sodium carbonate; NaOH= Sodium hydroxide; Colour rating: 1 – poor, 2 – fair, 3 – good, 4 – very good and 5 – excellent.

Table 4. Rating of colour fastness to dry and wet rubbing

Types of Dye	Fabric	Mordanting Techniques	Colour rating (1-5)	
			Dry	Wet
0.8 Na_2Co_3	Cotton	Pre-mordanting	5	3
		Meta-mordanting	5	3
		Post-mordanting	5	3
	Crepe	Pre-mordanting	5	3
		Meta-mordanting	5	2
		Post-mordanting	5	2
	Lycra	Pre-mordanting	5	4
		Meta-mordanting	5	2
		Post-mordanting	5	2
0.8 NaOH	Cotton	Pre-mordanting	5	4
		Meta-mordanting	5	3
		Post-mordanting	5	4
	Crepe	Pre-mordanting	5	4
		Meta-mordanting	5	2
		Post-mordanting	5	2
	Lycra	Pre-mordanting	5	4
		Meta-mordanting	5	3
		Post-mordanting	5	4

Note: Na_2CO_3= Sodium carbonate; NaOH= Sodium hydroxide; Colour rating: 1 – extremely staining, 2 – moderate staining, 3 – slightly staining, 4 – negligible staining and 5 – no staining

Table 5. Rating of colour fastness to alkaline perspiration

Types of Dye	Fabric	Mordanting Techniques	Colour rating (1-5)	
			Before test	After Test
0.8 Na_2Co_3	Cotton	Pre-mordanting	5	4
		Meta-mordanting	5	5
		Post-mordanting	5	3
	Crepe	Pre-mordanting	5	4
		Meta-mordanting	5	5
		Post-mordanting	5	2
	Lycra	Pre-mordanting	5	4
		Meta-mordanting	5	4
		Post-mordanting	5	3
	Cotton	Pre-mordanting	5	3
		Meta-mordanting	5	3
		Post-mordanting	5	5

0.8 NaOH	Crepe	Pre-mordanting	5	3
		Meta-mordanting	5	3
		Post-mordanting	5	3
	Lycra	Pre-mordanting	5	3
		Meta-mordanting	5	5
		Post-mordanting	5	5

Note: Na_2CO_3= Sodium carbonate; NaOH= Sodium hydroxide; Colour rating: 1 – poor, 2 – fair, 3 – good, 4 – very good and 5 – excellent.

Table 6. Rating of colour fastness to acid perspiration

Types of Dye	Fabric	Mordanting Techniques	Colour rating (1-5)	
			Before test	After Test
0.8 Na_2Co_3	Cotton	Pre-mordanting	5	4
		Meta-mordanting	5	4
		Post-mordanting	5	3
	Crepe	Pre-mordanting	5	4
		Meta-mordanting	5	4
		Post-mordanting	5	3
	Lycra	Pre-mordanting	5	3
		Meta-mordanting	5	4
		Post-mordanting	5	4
0.8 NaOH	Cotton	Pre-mordanting	5	3
		Meta-mordanting	5	2
		Post-mordanting	5	4
	Crepe	Pre-mordanting	5	2
		Meta-mordanting	5	2
		Post-mordanting	5	3
	Lycra	Pre-mordanting	5	3
		Meta-mordanting	5	3
		Post-mordanting	5	4

Note: Na_2CO_3= Sodium carbonate; NaOH= Sodium hydroxide; Colour rating: 1 – poor, 2 – fair, 3 – good, 4 – very good and 5 – excellent.

4. Conclusion

The effects of NaOH and Na_2CO_3 on dye extraction from coconut husk on cotton, crepe, and lycra fabrics, as well as the effect of different mordanting techniques on dyeing and colour fastness were investigated. According to the results, pre-mordanting is the least effective mordanting technique for all fabrics when dyed with NaOH dye extracts. The pre-mordanting technique produced lighter brown colours on cotton, crepe, and lycra. The colour strength of all fabrics dyed with Na_2CO_3 and NaOH dye extracts is in the following order: meta-mordanting > post-mordanting > pre-mordanting. Meta-mordanting with 12% tannic acid as mordant for lycra, cotton, and crepe fabrics improves the overall fastness properties against washing, rubbing, and perspiration. Thus, coconut husk dyes may serve as a greener alternative to their synthetic equivalents. With systematic research, it is hoped that natural colourants can be modified to meet the stringent functional characteristics of synthetic dyes and become a viable commercial alternative for the textile and apparel sectors.

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6. References

Ali, S., Jabeen, S., Hussain, T., Noor, S., & Siddiqua, U. H. (2016). Optimization of extraction condition of natural dye from pomegranate peels using response surface methodology. *International Journal of Engineering Sciences & Research Technology*, *5*(7), 542-48.

AATCC (2009). Colour fastness to washing. Technical Manual, Research Triangle Park, USA, p. 87-90.

Bechtold, T., Turcanu, A., Ganglberger, E., & Geissler, S. (2003). Natural dyes in modern textile dyehouses—how to combine experiences of two centuries to meet the demands of the future?. *Journal of Cleaner Production*, *11*(5), 499-509.

Gumrukcu, G., Ozgur, M. U., & Gultekin, C. (2008). Extraction of anthocyanin pigments from red onion (*Alliumcepa L.*) and dyeing woolen fabrics. *Asian Journal of Chemistry*, *20*(4), 2891.

Hassan, R. M., Zulrushdi, A. F., Yusoff, A. M., Kawasaki, N., & Hassan, N. A. (2015). Comparisons between Conventional and Microwave-Assisted Extraction of Natural Colourant from Mesocarp and Exocarp of *Cocus nucifera*. *Journal of Materials Science and Engineering*, *5*, 152-158.

Ismal, Ö. (2016). Patterns from nature: contact printing. *Journal of the Textile Association*, *77*(2), 81-91.

İşmal, Ö. E., & Yıldırım, L. (2019). Metal mordants and biomordants. In *The impact and prospects of green chemistry for textile technology* (pp. 57-82). Woodhead Publishing.

Prabhu, K. H., & Teli, M. D. (2014). Eco-dyeing using Tamarindus indica L. seed coat tannin as a natural mordant for textiles with antibacterial activity. *Journal of Saudi Chemical Society*, *18*(6), 864-872.

Prabhu, K. H., & Bhute, A. S. (2012). Plant based natural dyes and mordants: A Review. *J. Nat. Prod. Plant Resour*, *2*(6), 649-664.

Prabhu, K. H., Teli, M. D., & Waghmare, N. G. (2011). Eco-friendly dyeing using natural mordant extracted from Emblica officinalis G. Fruit on cotton and silk fabrics with antibacterial activity. *Fibers and Polymers*, *12*(6), 753-759.

Ramli, Q. H., Hassan, R. M., & Nor, N. M. (2021). Dyeing of Textile Using Different Mordants, Mordanting Techniques and Their Effects On Fastness Properties. *ASEAN Journal of Life Sciences*, *1*(2), 64-67.

Rodiah, M. H., Nur Asma Fhadhila, Z., Noor Asiah, H., Aziah, M. Y., & Kawasaki, N. (2018). Ultrasound-assisted Extraction of Natural Colourant from Husk of *Cocos nucifera*: A Comparison with Agitated-bed Extraction. *Pertanika Journal of Science & Technology*, *26*(3).

Rodiah, M. H., Hafizah, S. N., Asiah, H. N., Nurhafizah, I., Norakma, M. N., & Norazlina, I. (2022). Extraction of natural dye from the mesocarp and exocarp of *Cocos nucifera*, textile dyeing, and colour fastness properties. *Materials Today: Proceedings*, *48*, 790-795.

Samanta, A. K., & Agarwal, P. (2009). Application of natural dyes on textiles. *Indian Journal of Fibre and Textile Research*, 34 (4): 384-399.

Saxena, S., & Raja, A. S. M. (2014). Natural dyes: sources, chemistry, application and sustainability issues. In *Roadmap to sustainable textiles and clothing* (pp. 37-80). Springer, Singapore.