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Color Direction of Cotton Fabrics Dyed with Natural Dyes from *Areca catechu* and *Eusideroxylon zwageri* Using Various Fixators

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Abstract: The textile industry in Indonesia contributes significantly to the country's foreign exchange earnings, but synthetic dye waste has a negative impact on the environment. Natural dyes derived from plant waste can serve as an environmentally friendly alternative, but previous research has had limitations, such as low colorfastness, unstable colors, low pigment concentration, and suboptimal extraction and fixation methods. This study used 10 × 10 cm pieces of Hero cotton fabric dyed with natural dyes derived from areca nuts (*Areca catechu*) and ironwood (*Eusideroxylon zwageri*), which contain tannins that produce brown hues. The research process included scouring, mordanting, dyeing, fixation, and wet rub testing using 1% fixatives consisting of alum, lime, vinegar, tunjung salt, softener, and lemon. Color analysis was performed colorimetrically using a colorimeter app on an Android smartphone with L*, a*, and b* parameters. The results showed that all fixatives except lime increased brightness (L*). Alum, softener, and lemon reduced red intensity, while lime, vinegar, and rock salt increased it. All fixatives except lime reduced yellow intensity. The wet rub test caused an increase in brightness as well as a decrease in red and yellow intensity on the fixed fabric.

Keywords: Color direction; Cotton fabric; Fixator; Natural dyes

Introduction

The global demand for synthetic textile dyes has increased sharply. However, several developed countries, such as the Netherlands and Germany, have banned the use of synthetic dyes in textile products since 1996, referring to the CBI (Center for the Promotion of Imports from Developing Countries) Ref. CBI/NB-3032 (1996) concerning dyes for clothing, footwear, and bed linen. This prohibition was based on concerns regarding product degradation, environmental impacts, and health risks (Adriani & Zarwinda, 2019).

Natural dyes are alternative dyes that are renewable, biodegradable, non-toxic, and generally environmentally friendly (Suena et al., 2023). The novelty of this study lies in the utilization of areca nut (*Areca catechu*) and ulin wood (*Eusideroxylon zwageri*) waste as natural textile dye sources combined with various mordants, namely alum, lime, vinegar, ferrous sulfate, softener, and lemon, as well as the analysis of color direction using the L*, a*, and b* colorimetric method. This study is important because the use of synthetic dyes in the textile industry may cause environmental pollution; therefore, environmentally friendly and sustainable natural dye alternatives are required through the utilization of plant waste that has not been optimally developed.

The textile industry in Indonesia contributes significantly to national revenue, yet the waste generated from synthetic dyes poses a serious environmental threat. Disposal of textile dye waste can contaminate water and soil, leading to adverse health effects. Synthetic dyes are widely used due to their low cost, durability, and availability; however, their residues are harmful to the environment. As an alternative, natural dyes derived from plants and other natural sources are more environmentally friendly, biodegradable, and safe for use (E. B. Lestari &

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Permatasari, 2023). The application of natural dyes offers a potential solution to mitigate the negative impacts of synthetic dye waste while supporting the sustainability of the textile industry amidst growing market demands (Lestari et al., 2020). Furthermore, several clothing brands are known to employ synthetic textile dyes such as azo and acrylic. Azo dyes are carcinogenic and may cause bladder and kidney cancers when accumulated in the human body (Chung, 2016).

The market price of areca nut (Areca catechu) has experienced a significant decline, from approximately IDR 20,000 per kg to IDR 13,000 per kg, due to the increased yields from areca nut plantations. This condition has led many farmers to stop harvesting areca nuts, resulting in underutilization of areca nut waste in West Borneo. The application of areca nut seeds as natural dyes is relatively simple, involving drying and grinding of the seeds. Phytochemical analyses reveal that areca nut seeds contain alkaloids, flavonoids, tannins, and phenolic compounds, with catechin identified as the main coloring component (Pradeep et al., 2019). Environmental factors such as pH, oxygen, and temperature play a crucial role in determining the color outcomes produced by catechin. In addition to catechin, areca nut also contains tannins, which contribute to the dyeing properties. The color and its brightness can be influenced by treatments with acids, alkalis, or metallic salts. Tannins in areca nut are known to produce a lemon-yellow hue. The objective of this study is to determine the effect of mordants and wet rubbing tests on the color direction of cotton fabrics dyed with areca nut seeds and ironwood (Eusideroxylon zwageri).

Many industries utilize wood as raw material for various high-value products. However, this practice has led to increased forest exploitation and the generation of wood waste that has not been optimally managed, thereby creating new environmental problems (Tampubolon, 2020). Various types of wood waste are produced by the wood-processing industry, including bark residues, wood offcuts, wood chips, and sawdust or other solid wastes. Such waste typically originates from sawmills and the pulp and paper industry. In Kalimantan, however, wood waste management remains suboptimal, even though ironwood (Eusideroxylon zwageri) sawdust has great potential as a natural textile dye due to its tannin content, which can be extracted through boiling to produce a reddish-brown color (Lestari et al., 2020). Most communities only use it as firewood for cooking, while bark residues are used for handicrafts. In many cases, wood waste is still disposed of by burning or dumping into rivers, causing significant environmental pollution, particularly in the air and water (Lingga et al., 2023).

The brown to blackish color produced by tannins in ironwood sawdust (Eusideroxylon zwageri) demonstrates its role as a natural dye. Utilizing ironwood waste as a dye could help reduce its environmental accumulation and mitigate pollution risks (Setyowati et al., 2024).

Natural dyes offer several advantages, including easy availability, biodegradability, and environmental friendliness. The use of natural dyes in the textile industry, particularly in batik production, has continued to increase due to the abundant availability of raw materials. By utilizing plant-based natural dyes, the textile industry can contribute to environmental conservation while simultaneously creating products that are healthier and more aesthetically appealing for consumers.

Natural dyes tend to produce soft, classic tones; therefore, a fixation process is required to lock in and enhance color variations. Through fixation, the resulting color becomes sharper and more durable. Fixation serves to secure the dye within the fabric fibers after the dyeing process, preventing it from easily fading (Susiati & Kartikasari, 2017). Fixatives are applied to increase the absorption of natural dyes by fabrics and can be categorized into two types: synthetic and natural. Synthetic fixatives such as ferrous sulfate, lime, alum, vinegar, and softener improve the binding of dyes to fibers, while natural fixatives such as lemon juice are also utilized in this study. However, the application of vinegar and softener as fixatives in textile dyeing remains limited. The use of both synthetic and natural fixatives provides broader alternatives for improving the quality of natural dyeing, although further research is required to evaluate their effectiveness.

The L* a* b* color space, also known as the CIELAB method, is the most comprehensive color space established by the International Commission on Illumination (Commission Internationale de l'Éclairage, or CIE). This color model is capable of representing all colors visible to the human eye and is widely used as a reference in various color applications (Rulaningtyas et al., 2015). The CIELAB method defines color in a three-dimensional space consisting of three axes: L*, where 0 = black and 100 = white; a*, where positive values represent red and negative values represent green; and b*, where positive values indicate yellow and negative values indicate blue. The objective of this measurement is to analyze fabric color properties in terms of lightness (L*), red–green intensity (a*), and yellow–blue intensity (b*). The influence of fixatives on color direction can be illustrated in Figure 1.

Method

This section provides a detailed description of the materials and procedures, as well as the specific methods employed in the research.

Time and Place of Research

The research was conducted over a period of 4 months at the Chemistry Laboratory, Faculty of Teacher Training and Education, Universitas Tanjungpura, Pontianak.

Research Tools and Materials

The instruments used in this study included an analytical balance (Aduanx Innotech), pot, gas stove, wooden spoon, knife, blender (KLAZ), water measuring glass, basin, pH meter (V2), mini studio box (Puluz), smartphone camera (Samsung A55), and a colorimeter (Lab Tools Apps, Playstore). The materials utilized were areca nut (Areca catechu) and ulin wood (Eusideroxylon zwageri) as natural dyes, with fixatives consisting of ferrous sulfate ($FeSO_4$), lime, alum, softener, vinegar, and natural lemon extract. Additional materials included hero cotton fabric, water, soda ash, Turkey Red Oil (TRO), and bar soap.

Research Procedure

Collection and Preparation of Plant Samples

Samples of areca nut (Areca catechu) were obtained from Dusun Semberang 1, Sumber Harapan Village, Sambas District, Sambas Regency, West Kalimantan, while ulin wood (Eusideroxylon zwageri) samples were collected from Rumah Ulin, Pontianak City. The samples were cleaned of impurities and washed with running water. After washing, the samples were sliced using a knife and air-dried at room temperature. Once dried, the samples were ground into a fine powder.

Preparation of Dye Extract

The extraction method used was the boiling (decoction) method. A total of 200 grams of sample was boiled in 3 liters of water at 100 °C for approximately 1 hour in a single extraction process. After cooling, the extract was filtered using a tea strainer and was then ready for use.

Preparation of Fixators

Fixators were prepared at a concentration of 1%. Ferrous sulfate, lime, and alum were each weighed at 1 g and dissolved in 1 L of water. Meanwhile, softener, vinegar, and lemon juice were each measured at 10 mL and diluted in 1 L of water. The solutions were then placed in separate containers and made ready for use.

Fabric Dyeing

Cotton Fabric Preparation

The cotton fabric was prepared in pieces measuring 10 cm × 10 cm, with a total of 12 samples.

Scouring

The scouring process aims to remove impurities in the fibers, particularly fats and oils (Kuntari, 2006). The cotton fabric was first washed using Turkey Red Oil (TRO) powder. TRO powder (2 g/L) was dissolved in water, after which the fabric was immersed in the solution and soaked for approximately 15 minutes. The fabric was then rinsed with running water and air-dried at room temperature until completely dry.

Mordanting of Cotton Fabric

The purpose of the mordanting process is to enable the fabric to effectively absorb the dye solution. The mordanting process begins by boiling 420 g of alum and 80 g of soda ash in 5 liters of water. The fabric is then immersed in the solution and boiled for 1 hour. After boiling, the fabric is placed in a closed container and left to stand for 24 hours. Finally, the fabric is air-dried at room temperature (±25 °C) in a shaded area, protected from direct sunlight (Tiara et al., 2024).

Dyeing Process

The dyeing process was carried out by immersing mordanted cotton fabrics into the dye extract. Six containers were prepared, each containing one fabric sample, and the fabrics were soaked in the extract until fully submerged for 24 hours. Afterward, the fabrics were air-dried at room temperature. This procedure referred to the method of Tiara et al. (2024) and was also applied to the other four samples.

Fixation Process of Fabric

After the air-drying process, the dyed fabrics underwent fixation using mordants such as ferrous sulfate, lime, alum, softener, vinegar, and lemon extract. Six containers were prepared, each for one fabric sample. Each sample was immersed in the ferrous sulfate solution for 15 minutes to allow absorption. Subsequently, the fabrics were air-dried again at room temperature until completely dry. The same procedure was applied for the other mordants, lime, alum, softener, vinegar, and lemon extract.

Wet Rubbing Test

After fixation, the samples underwent a wet rubbing test by rubbing each fabric piece with a bar soap solution. The fabrics were then air-dried at room temperature until completely dry.

Color Direction Test

The color direction test referred to the method of Haerudin et al. (2019), using a colorimeter application on an Android device. The test was conducted with a smartphone camera in live mode within a photobox. After scanning, the data were exported and presented in Excel format. The procedure for testing color direction with fixatives is illustrated in Figure 1.

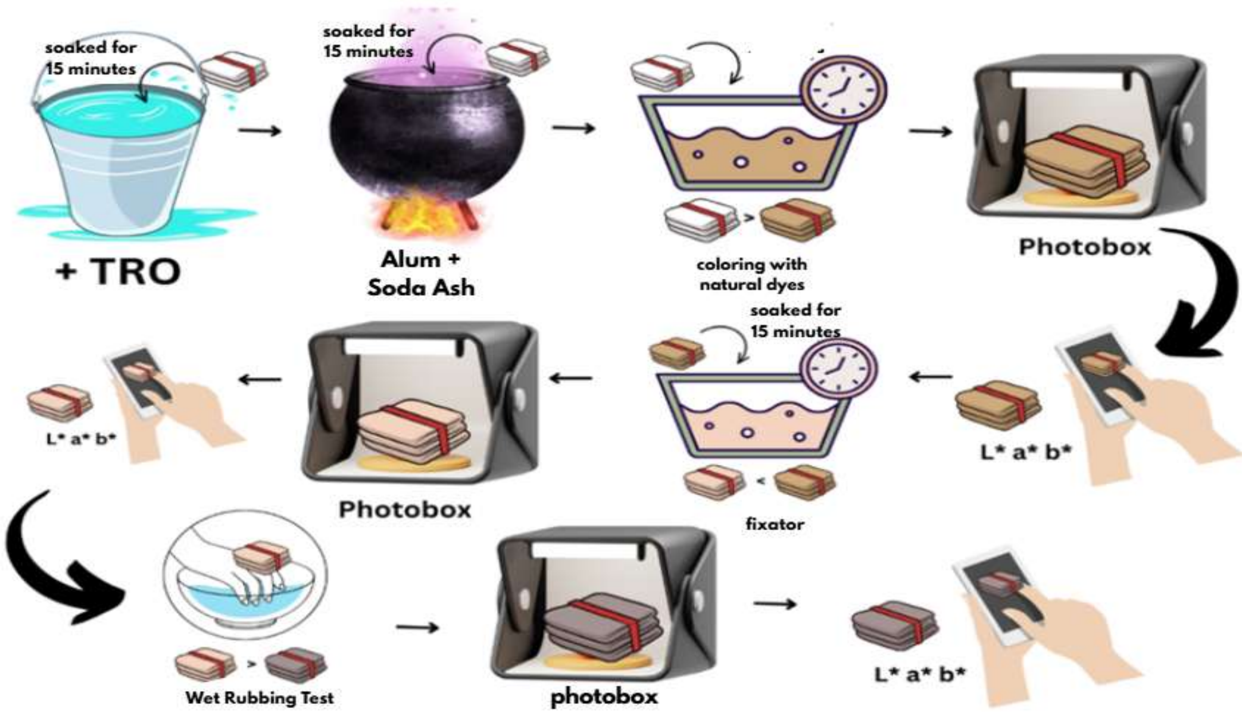


Figure 1. Procedure for testing color direction with a fixator

Result and Discussion

The determination of the color direction of cotton fabric dyed with natural colorants from areca nut and ironwood was carried out in three stages: dyeing, fixation, and wet rubbing tests. Dyeing was performed on Hero cotton fabric using extracts from areca nut (*Areca catechu*) and ironwood (*Eusideroxylon zwageri*). Cotton fabric was chosen as the medium for natural dyeing due to its affordability and eco-friendly nature. As a natural fiber, cotton is widely used in clothing because it is biodegradable, soft, comfortable, warm, hygroscopic, and renewable, thereby supporting environmental sustainability (Eddy et al., 2016).

Before the dyeing process, the fabric underwent a mordanting treatment. According to Hernani et al. (2017), mordants play a role in binding dyes to fabrics by forming chemical bridges between dye molecules and fiber, thereby improving the efficiency of the dyeing process. This study employed alum and soda ash as mordanting agents. Soda ash helps to level the dyeing results, producing more stable colors on the fabric. It also facilitates dye absorption by opening the fiber structure, as its high pH dissolves fats present in the fibers. Alum, on the other hand, stabilizes the pigment on the fibers. The aluminum ions contained in alum interact with the hydroxyl groups of cellulose, allowing natural dyes to adhere more strongly and last longer. The combination of soda ash and alum works synergistically: soda ash opens the fibers to facilitate dye absorption, while alum stabilizes the absorbed dyes, enhances color fastness, and produces more durable shades on the fabric (Mayliana, 2016).

The extracts of areca nut and ironwood contain tannins, which are water-soluble polyphenolic compounds composed of phenolic hydroxyl groups, enabling effective binding with proteins and other macromolecules. Tannins are capable of coloring fibers and enhancing overall shade depth (Lestari et al., 2020). The interaction between alum mordant and cellulose fibers involves chemical reactions between aluminum ions (Al^{3+}) in alum and hydroxyl groups (-OH) in cellulose molecules. Alum acts as a bridge between the natural dye molecules and the cellulose fibers. When applied as a mordant, Al^{3+} ions bind to the hydroxyl groups of cellulose, forming chemical complexes that increase dye uptake by the fibers. In the application of tannin pigments, Al^{3+} ions also bind with hydroxyl groups of tannins, thereby strengthening the interaction between the dye and fiber. The reaction between cellulose fibers of cotton, tannins, and alum mordant is illustrated in Figure 2.

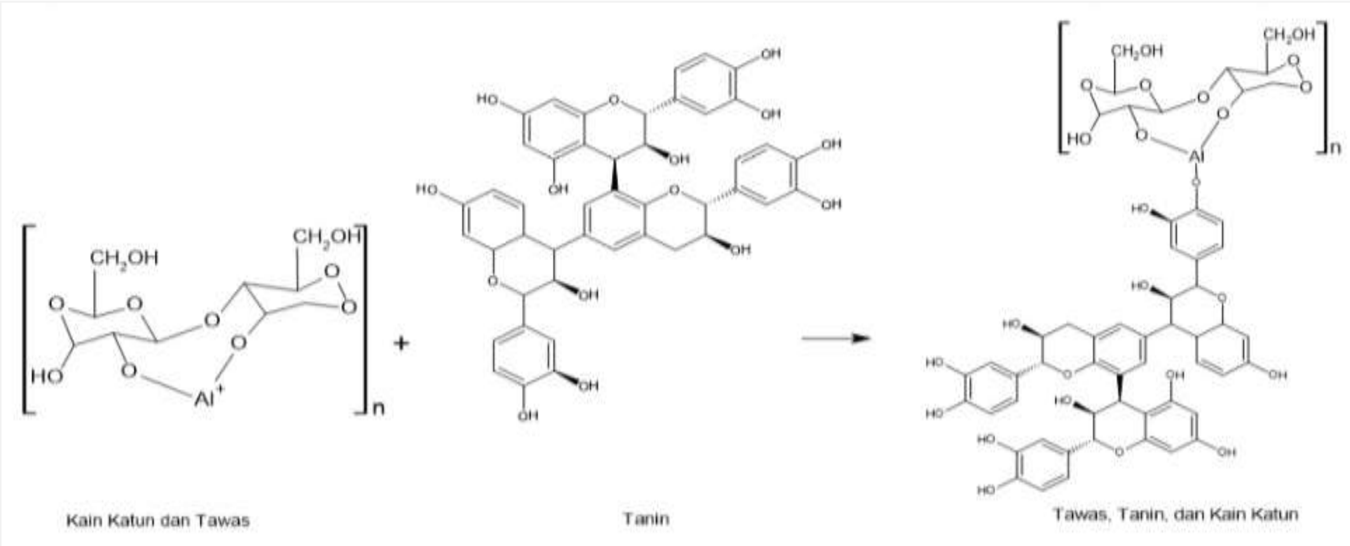
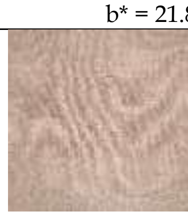
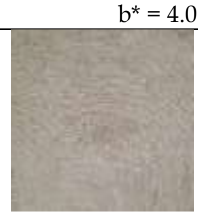


Figure 2. Reaction between cellulose fiber from cotton with tannin and alum mordant

Table 1. Color Direction of Cotton Fabric with Areca Catechu Extract with Various Fixators

Fixation		Color Direction					
		Control		After Fixation		After Wet Rubbing	
Alum	Color Names and Pictures of Fabrics	Barley Corn		Navajo White		Silver	
	CIELAB Data		L*= 83.5 a* = 11.3 b* = 28.0		L* = 83.5 a* = 11.3 b* = 28.0		L* = 80.8 a* = 1.1 b* = 14.9
Lime	Color Names and Pictures of Fabrics	Barley Corn		Dark Salmon		Silver	
	CIELAB Data		L* = 62.6 a* = 18.4 b* = 30.0		L* = 73.2 a* = 23.5 b* = 35.9		L* = 79.3 a* = 1.5 b* = 8.4
Vinegar	Color Names and Pictures of Fabrics	Sepia Brown		Yello-wish Brown		Silver	
	CIELAB Data		L* = 53.2 a* = 19.6 b* = 31.2		L* = 69.9 a* = 12.1 b* = 21.8		L* = 76.4 a* = 3.4 b* = 4.0
Ferrous Sulfate	Color Names and Pictures of Fabrics	Barley Corn		Silk Brown		Silk Brown	
	CIELAB Data		L* = 61.4 a* = 13.8 b* = 33.2		L* = 71.7 a* = 8.0 b* = 11.0		L* = 71.1 a* = 6.0 b* = 5.1

Fixation		Color Direction		
		Control	After Fixation	After Wet Rubbing
Softener	Color Names and Pictures of Fabrics	Sepia Brown 	Yello-wish Brown 	Dark Gray 
	CIELAB Data	L* = 53.0 a* = 19.0 b* = 35.4	L* = 79.5 a* = 15.1 b* = 22.5	L* = 73.3 a* = 3.0 b* = 3.9
Lemon Extract	Color Names and Pictures of Fabrics	Sepia Brown 	Dark Salmon 	Silver 
	CIELAB Data	L* = 48.0 a* = 23.4 b* = 38.3	L* = 72.3 a* = 14.6 b* = 34.4	L* = 81.6 a* = -1.4 b* = 7.3

The color direction of cotton fabrics before and after fixation and wet rubbing tests is presented in Tables 1 and 2. Based on these tables, it can be observed that both natural dye samples applied to cotton fabric predominantly produced brown shades.

Effect of Mordants on the Color Direction of Cotton Fabric

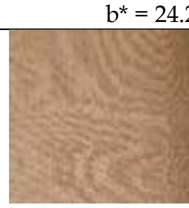
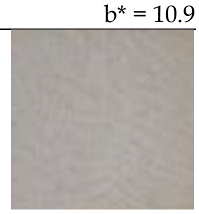
Natural dyes from areca nut (Areca catechu) yield color variations depending on the type of mordant used. Before the fixation process, the natural dye applied to hero cotton fabric produced a dark brown shade. However, according to Prabawa (2014), the dye extract from areca nut produced a reddish-brown color when applied to cotton fabric. This difference occurred because Prabawa (2014) study used a dyeing procedure at 80–100°C for 30 minutes, whereas the present study was conducted at room temperature with an immersion time of 24 hours, making color variations on the fabric highly probable.

After fixation, changes in L*, a*, and b* values were observed on the cotton fabric. Fabrics dyed with areca nut extract showed an increase in L* values across all mordants. The fabric fixed with softener exhibited the highest brightness, while the fabric fixed with alum showed the lowest brightness. The order of brightness values from highest to lowest was: softener, lemon, vinegar, ferrous sulfate, lime, and alum. The softener mordant (pH 6) showed the greatest brightness difference because it contains 8% cationic surfactants. This component can enhance the brightness of fabric color but also has the potential to cause fading, particularly with natural dyes or less stable colorants. This indicates that tannins in areca nut at pH 6 tend to produce dark brown shades. Based on this study, it can be concluded that cationic surfactants can increase brightness while also causing fading, leading the fabric color to approach the base color of cotton, which is white.

Cotton fabrics dyed with areca nut extract showed an increase in a* values after fixation with lime, while the other five mordants decreased red color intensity. Lime produced the highest red intensity, while lemon resulted in the lowest. The order of a* values from highest to lowest was: lime, alum, softener, ferrous sulfate, vinegar, and lemon. The highest red intensity was obtained with lime as the mordant. The alkaline condition of lime solution (pH 11) triggers chemical changes in the dye, producing brighter shades. The calcium hydroxide content in lime plays a role in opening the pores of cotton fibers, enhancing dye absorption (Umaira & Adriani, 2024). This means that tannins from areca nut at pH 11 result in bright light-brown colors. Based on this study, it can be concluded that calcium hydroxide in tannins can increase red color intensity, making the shades appear brighter.

The yellow intensity (b*) values also showed a decrease. After fixation, all mordants decreased yellow intensity, except lime. Lime produced the highest yellow intensity, while ferrous sulfate produced the lowest. The order of b* values from highest to lowest was: lime, alum, lemon, vinegar, softener, and ferrous sulfate. The highest yellow intensity was produced with lime due to its alkaline nature (pH 11) and calcium hydroxide content. Conversely, ferrous sulfate produced the lowest yellow intensity because of its acidic pH (pH 3). In tannin compounds, acidic pH influences the performance of the compound. Metal ions in ferrous sulfate form complexes with tannins, which tend to reduce color intensity (Lestari et al., 2020). Based on this study, it can be concluded that ferrous sulfate, through its metal ions, reduces yellow color intensity.

Table 2. Color Direction of Cotton Fabric with Ironwood Extract with Various Fixators

Fixators		Color Direction: Control	Color Direction: After Fixation	Color Direction: After Wet Rubbing
Alum	Color Names and Pictures of Fabrics	Fallow Brown 	Yello-wish Brown 	Fallow Brown 
	CIELAB Data	L* = 67.5 a* = 13.7 b* = 32.2	L* = 63.7 a* = 11.1 b* = 26.9	L* = 66.0 a* = 8.6 b* = 21.2
Lime	Color Names and Pictures of Fabrics	Fallow Brown 	Gold Orange 	Cloudy Brown 
	CIELAB Data	L* = 63.7 a* = 11.1 b* = 26.9	L* = 55.7 a* = 48.1 b* = 49.0	L* = 68.4 a* = 0.7 b* = 6.1
Vinegar	Color Names and Pictures of Fabrics	Fallow Brown 	Yello-wish Brown 	Cloudy Brown 
	CIELAB Data	L* = 63.6 a* = 10.3 b* = 31.1	L* = 77.6 a* = 13.2 b* = 24.1	L* = 67.2 a* = 1.6 b* = 8.7
Ferrous Sulfate	Color Names and Pictures of Fabrics	Barley Corn 	Silk Brown 	Silk Brown 
	CIELAB Data	L* = 56.1 a* = 12.8 b* = 34.9	L* = 70.5 a* = 9.0 b* = 13.7	L* = 69.5 a* = 11.1 b* = 12.3
Softener	Color Names and Pictures of Fabrics	Barley Corn 	Yello-wish Brown 	Silk Brown 
	CIELAB Data	L* = 61.4 a* = 13.8 b* = 33.2	L* = 74.6 a* = 13.0 b* = 24.2	L* = 68.6 a* = 7.7 b* = 10.9
Extract Lemons	Color Names and Pictures of Fabrics	Barley Corn 	Pale Golden Rod 	Silver 
	CIELAB Data	L* = 61.4 a* = 13.8 b* = 33.2	L* = 79.9 a* = 11.1 b* = 18.1	L* = 80.8 a* = 2.3 b* = 1.4

Natural dye from ironwood (*Eusideroxylon zwageri*) produces a variety of colors depending on the type of mordant used. Prior to fixation, the natural dye applied to Hero cotton fabric resulted in a light brown color derived from tannins. This finding is consistent with Nintasari et al. (2016), who reported that ironwood extract produces brown coloration when applied to cotton fabric. Differences in color intensity and brightness between studies may result from variations in procedures. For example, with Nintasari et al. (2016) conducted dyeing for 15 minutes at room temperature, while the present study applied a 24-hour immersion, which likely contributed to color differences. Fixation is required to direct the color outcome on cotton fabric.

Fixation strengthens and modifies the characteristics of natural dyes depending on the type of metal bound, while simultaneously locking the dye absorbed into the fiber (Pujilestari, 2014). Fixation of Hero cotton fabric dyed with ironwood extract using alum, lime, vinegar, ferrous sulfate, softener, and lemon resulted in variations in lightness (L*), red-green intensity (a*), and yellow-blue intensity (b*). Fabrics dyed with ironwood extract showed an increase in L* values for all mordants except alum and lime. The lemon mordant (pH 2.8) produced the highest increase in lightness, while lime showed the greatest decrease. The order of lightness values, from highest to lowest, was lemon, ferrous sulfate, vinegar, softener, alum, and lime. The highest increase in brightness with lemon is due to tannins producing paler colors under acidic conditions. At low pH, tannins undergo hydrolysis, altering their chemical structure, decreasing stability and color intensity (Chadijah et al., 2021). This reduces tannins' ability to form stable color bonds with fibers, resulting in paler hues approaching the base color of the fabric.

For red intensity (a*), fabrics dyed with ironwood extract mostly showed a decrease, except when fixed with lime and vinegar. Lime mordant produced the highest red intensity, attributed to its alkaline properties. The order of a* values from highest to lowest was lime, vinegar, softener, alum, lemon, and ferrous sulfate. At pH 11, tannins in ironwood yield reddish-brown coloration. This study indicates that calcium hydroxide in lime enhances red intensity, producing brighter shades.

For yellow intensity (b*), all mordants reduced values except lime, with the largest decrease observed in ferrous sulfate. Lime, being alkaline, produced brighter shades (Umaira & Adriani, 2024). The order of b* values from highest to lowest was lime, alum, vinegar, softener, lemon, and ferrous sulfate. These results demonstrate that calcium hydroxide in tannins can intensify reddish coloration, making the fabric appear darker.

Effect of Wet Rubbing Test on Cotton Fabric Color Direction

Natural dyes tend to fade depending on the mordant used, making wet rubbing tests essential. For example, ironwood extract fixed with lime initially appeared as a bright golden orange, but after wet rubbing, the color faded to a cloudy brown due to the interaction between tannins and alkaline soap, leading to color loss.

After wet rubbing, cotton fabrics dyed with areca nut extract exhibited significant changes in L*, a*, and b* values. Lightness (L*) increased, while red-green (a*) and yellow-blue (b*) intensities decreased. Lemon mordant showed the highest increase in brightness, while softener displayed the most significant decrease. The order of L* values, from highest to lowest, was lemon, vinegar, lime, ferrous sulfate, alum, and softener. Tannins treated with alkaline soap undergo emulsification, breaking down fats and dirt into smaller particles that are easily rinsed (Li et al., 2025) detergent content in soap can also disrupt the bonds between dye molecules and fabric fibers.

For red intensity (a*), all cotton fabrics dyed with areca nut extract showed a decrease after wet rubbing, with the highest reduction observed in lime-fixed fabrics and the lowest in ferrous sulfate-fixed fabrics. The order of a* values from highest to lowest was lime, lemon, softener, alum, vinegar, and ferrous sulfate. Similarly, yellow intensity (b*) decreased in all samples, with lime showing the greatest decrease and ferrous sulfate the least. The order of b* values from highest to lowest was lime, lemon, softener, vinegar, alum, and ferrous sulfate. These results indicate that lime mordant is less effective at retaining natural dyes under alkaline soap treatment.

For fabrics dyed with ironwood extract, wet rubbing caused decreases in brightness (L*) for ferrous sulfate, softener, and vinegar mordants, while lime, alum, and lemon increased brightness. The order of L* values from highest to lowest was lime, alum, lemon, vinegar, softener, and ferrous sulfate. Tannins treated with soap undergo emulsification, making the color approach the natural whiteness of the fabric. All fabrics experienced a decrease in red intensity (a*) except those fixed with ferrous sulfate, with lime showing the highest reduction, followed by vinegar, lemon, softener, alum, and ferrous sulfate. Yellow intensity (b*) also decreased for all mordants, with the largest reduction in lime, followed by lemon, vinegar, softener, alum, and ferrous sulfate. This indicates that lime mordant is less effective at preserving dye bonds in soapy conditions.

Tables 1 and 2 present the L*, a*, and b* values after wet rubbing. Overall, the results indicate that the binding between natural dyes and mordants was relatively weak, leading to suboptimal color retention.

Conclusion

Based on the research conducted, it can be concluded that extracts of *Areca catechu* (areca nut) and *Eusideroxylon zwageri* (ulin wood) can be utilized as natural textile dyes. The novelty of this study lies in the utilization of areca nut and ulin wood waste as natural dye sources combined with various mordants, namely alum, lime, vinegar, ferrous sulfate, softener, and lemon. The results showed that all mordants, except lime, increased the lightness value (L*). Alum, softener, and lemon tended to reduce the red color intensity, whereas lime, vinegar, and ferrous sulfate increased the red intensity. All mordants, except lime, also reduced the yellow color intensity. The wet rubbing test demonstrated that mordanted fabrics experienced an increase in lightness and a decrease in red and yellow color intensities due to color fading under alkaline conditions. Each mordant exhibited a different effect on the hue direction and color intensity of the fabric. This study indicates that the use of natural dyes derived from plant waste has the potential to support the development of environmentally friendly textiles, reduce the use of synthetic dyes, and enhance the utilization value of plant waste as a sustainable dye source. However, this study still has several limitations, particularly the low color fastness in the wet rubbing test and the absence of other color fastness evaluations, such as washing and light exposure tests. Therefore, further studies are recommended to develop more stable mordant combinations, optimize fixation methods, and evaluate the application of natural dyes on various textile fabrics to improve color quality and durability.

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