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Ecoprint Motif Analysis Using Young Teak Leaves with Tunggung Fixation Applied to Artificial Fibers

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Abstract: This study aims to analyze the effect of tunjung (ferrous sulfate) fixation duration on the color quality and motif clarity of ecoprinted fabrics made from young teak (Tectona grandis) leaves applied to artificial fibers. The research supports the development of eco-friendly natural dye applications and innovation in textile and fashion education. A descriptive quantitative method was used, employing trend and percentage analyses based on evaluations from three textile experts. The assessment covered five aspects: color brightness, motif clarity, motif arrangement neatness, cleanliness, and overall appearance. The results showed that fixation durations of 10, 30, and 60 minutes did not significantly influence color brightness or motif quality, indicating that the dye–fiber bonding equilibrium was achieved within 10 minutes. However, qualitative observations revealed that samples fixed for 30 minutes exhibited slightly clearer motifs due to mild oxidation and pigment redistribution during steaming and drying. These findings suggest that a 10-minute fixation duration is sufficient for efficient dye bonding, while a 30-minute duration may enhance visual definition. The study contributes to sustainable textile innovation by demonstrating that teak leaf pigments combined with tunjung mordant can produce eco-friendly, visually appealing fabrics suitable for fashion and textile learning.

Keywords: Artificial fibers; Ecoprint; Textile motif; Tunjung fixation; Young teak leaves

Introduction

Indonesia is known as a tropical country with rich biodiversity and abundant natural resources that can be utilized for the development of creative industries, including the textile sector. Among these resources, young teak leaves (*Tectona grandis*) contain natural pigments such as anthocyanins and tannins that produce reddish-purple hues suitable for eco-friendly textile dyeing (Fazruza et al., 2018). According to Alegbe et al. (2024), the use of natural dyes in the textile industry is a strategic step to reduce dependency on synthetic dyes, which are known to cause environmental pollution. Natural dyes are biodegradable, non-toxic, and aligned with the principles of sustainability, making them increasingly relevant to the development of green textile innovations (Indraningsih, 2014). One of the environmentally friendly dyeing methods gaining attention is the ecoprint technique, defined by Maharani (2018) as the transfer of natural motifs onto fabrics through direct contact with plant materials, followed by steaming or heating.

Although numerous studies have investigated the use of natural fibers in ecoprinting, limited attention has been paid to the application of young teak leaves on artificial fibers and the influence of tunjung (ferrous sulfate) fixation duration on color and motif quality. Addressing this gap, the present study aims to optimize fixation duration to achieve the best visual and color results while promoting sustainable practices in textile education. Recent research by Gecchele et al. (2021) highlighted that optimizing anthocyanin extraction from plant sources can improve dyeing efficiency and pigment stability. Similarly, Pizzicato et al. (2023) and Negi et al. (2025) emphasized that plant-based dyeing systems represent essential pathways toward achieving sustainability in the global textile industry.

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Pandansari et al. (2022) explain that ecoprint belongs to the category of plant-based textile dyeing that not only produces artistic and natural visual motifs but also contributes to sustainable textile innovation through eco-friendly processing methods. Cristea et al. (2006) and Burkinshaw et al. (2009) further demonstrated that the use of metallic mordants, particularly $FeSO_4$ and tannic acid, can significantly enhance dye uptake, color intensity, and fastness on textile fibers. A crucial stage in the ecoprint process is fixation or mordanting, where metallic salts such as ferrous sulfate (locally known as *tunjung*) or aluminum are used to bind the dye to fabric fibers, improving color fastness and durability. Sedjati (2019) states that ferrous sulfate enhances both color intensity and resistance to washing and sunlight exposure. This finding is supported by Baaka et al. (2023), who observed that mineral-based mordants increased color stability by up to 30% compared to untreated fabrics. In a related study, Wardani et al. (2022) and Rahmawati et al. (2021) found that the application of $FeSO_4$ in teak leaf ecoprint improved motif clarity and color depth, reinforcing the role of ferrous ions in the natural dyeing process.

While most previous studies focused on natural fibers such as cotton, linen, and silk (Widiawati et al., 2009; Dantes & Aprianto, 2017), applications of ecoprint on artificial fibers remain relatively unexplored. However, Nguyen (2025) demonstrated that artificial fibers can successfully absorb anthocyanin-based dyes when treated with metal mordants such as $FeSO_4$, while Emerald Group (2024) revealed that biomordants could further enhance the dye affinity and environmental performance of synthetic textiles. Artificial fabrics such as ruby silk, with their smooth and glossy texture resembling natural silk, thus offer promising potential for innovation in natural dyeing techniques. This potential is further supported by Mouro et al. (2023), who developed bio-active dyeing strategies using natural pigments and sustainable solvents, and Grande et al. (2024), who demonstrated that natural dye microencapsulation can enhance the durability and color retention of eco-dyed fabrics.

Beyond its technical and aesthetic dimensions, ecoprint also holds educational and cultural significance, particularly in vocational and textile education. Sariputra (2020) emphasizes that natural dyeing practices can be integrated into sustainable fashion design education to foster creativity and environmental awareness among students. Likewise, Jabar et al. (2023) highlight that the ethnobotanical use of local plants for natural dyes provides strong cultural and scientific learning opportunities in education. In a broader context, Dey (2024) underscores that eco-dyeing and ecoprint practices play a vital role in raising global awareness of environmentally responsible fashion production. Supporting this perspective, Setiawan et al. (2022) reported that integrating eco-fashion project-based learning enhances students' understanding of sustainability in textile design.

Based on this background, the present study focuses on analyzing the color and motif characteristics of ecoprint using young teak leaves with ferrous sulfate fixation applied to artificial fibers. The objective of this research is to examine the effect of different fixation durations on the visual and aesthetic quality of ecoprint results, while contributing to the development of efficient, eco-friendly, and educationally relevant natural dyeing technologies in fashion and textile education.

Method

Research Design

This research employed an experimental quantitative design to examine the effect of fixation duration on the color intensity and motif quality of ecoprinted fabrics using young teak leaves (*Tectona grandis*). According to Creswell (2014), an experimental design is suitable when the researcher intends to identify the influence of one or more independent variables on dependent variables through controlled treatment. In this study, the independent variable was the duration of fixation using ferrous sulfate (*tunjung*), while the dependent variables were color intensity and motif clarity of the resulting ecoprint. The experiment was conducted in a textile laboratory setting to ensure consistency in environmental conditions such as temperature, humidity, and steam exposure time.

Materials and Tools

The fabric used in this study was artificial silk, commonly known as ruby silk. The natural dye source employed was young teak leaves (*Tectona grandis*), which contain natural pigments suitable for eco-friendly dyeing. Ferrous sulfate ($FeSO_4$) served as the fixative agent to enhance color fastness, while vinegar (CH_3COOH) and clean water were used as auxiliary agents throughout the dyeing process.

The equipment consisted of a steamer, measuring cups, pH meter, brush, digital camera, rubber ties, and an iron rod. Ruby silk was selected as the base material because of its soft texture, glossy surface, and ability to absorb natural pigments effectively (Indraningsih, 2014; Larasati & Murwanti, 2023).

Procedure

The research was conducted in four main stages: fabric preparation, dye application, fixation, and documentation. The overall process is illustrated in

Figure 1, which presents the experimental flow of natural dyeing using young teak leaves (*Tectona grandis*).

In the first stage, the fabric used in this study was artificial silk (ruby silk). It was scoured by boiling in a 5% vinegar (CH_3COOH) solution for 20 minutes to remove surface impurities and open the fiber pores. This pretreatment ensured optimal absorption of natural pigments during the dyeing process (Indrayani et al., 2020).

In the second stage, young teak leaves were arranged on the fabric surface according to predetermined motif patterns. The fabric was then rolled around an iron rod, tightly bound with rubber bands, and steamed for 90 minutes. After steaming, the bundles were allowed to cool naturally before unwrapping (Pandansari et al., 2022; Mukti et al., 2023).

The third stage involved the fixation process, which was carried out using a ferrous sulfate ($FeSO_4$) solution at a fixed concentration of 5 g/L, while the fixation duration served as the independent variable. The fabrics were immersed for 20, 30, and 60 minutes to evaluate the effect of fixation time on color intensity and motif clarity (Baaka et al., 2023; Alegbe et al., 2024).

In the final stage, the fabrics were thoroughly rinsed with clean water to remove residual mordant and dye, then air-dried at room temperature for 24 hours. The resulting color and motif variations were documented using digital photography for both qualitative and quantitative analysis (Wahyuningsih & Anggraeni, 2021).

Data Analysis

The collected data were analyzed using descriptive statistical techniques to determine the mean score, standard deviation, and tendency level of each variable. Descriptive analysis is appropriate for describing observed phenomena systematically without hypothesis testing when dealing with small-scale experiments (Sugiyono, 2019). The mean (M) was calculated using the following formula:

$$M = \frac{\sum X}{\mathrm{N}} \quad (1)$$

Where: M = Mean score; $\sum$ X = Total Score obtained; N = Number of sample. The standard deviation (SD) was calculated as follows:

$$SD = \sqrt{\frac{\Sigma(X-M)^2}{N}} \quad (2)$$

Where: SD = Standard deviation; X = Individual score; M = Mean score; N = Number of samples.

To determine the tendency level of the data, the Ideal Mean (Mi) and Ideal Standard Deviation (SDi) were used, calculated as follows (Sugiyono, 2019):

$$Mi = \frac{X_{ideal\_max} + X_{ideal\_min}}{2} \quad (3)$$

$$SDi = \frac{X_{ideal\_max} + X_{ideal\_min}}{6} \quad (4)$$

Where:
*M*i = Ideal mean
*SD*i = Ideal Standar Deviation
X_{ideal_max} = Highest ideal score
X_{ideal_min} = Lowest ideal score

The comparison between MMM (actual mean) and MiMiMi (ideal mean) was then used to classify the tendency level of the results into categories such as very effective, effective, moderate, less effective, or ineffective. These classifications helped interpret the relationship between fixation duration and the resulting ecoprint quality.

Result and Discussion

Result

This study examined the effects of fixation duration using tunjung (ferrous sulfate) on the color and motif of ecoprint produced from young teak leaves (*Tectona grandis*) applied to artificial fibers. Three fixation durations—10, 30, and 60 minutes—were tested to evaluate differences in color brightness, motif clarity, motif arrangement, cleanliness, and overall visual quality.

Overall, the findings revealed that fixation time did not produce substantial variations in color brightness or motif definition. Across all treatments, the resulting hues were dominated by reddish-purple tones, which are typical of the natural pigments *anthocyanins* and *tannins* contained in young teak leaves.

Figure 1. Preparation of teak leaves for eco-printing

Figure 2. Fixation and steaming process using tunjung

Figure 3. Final ecoprint results after drying

Table 1. Distribution of Color Brightness Scores for the 10-Minute Fixation Treatment

Assessment Aspects	Assessment Score			
	4	3	2	1
Color Brightness	$P = x\ 100\% \frac{3}{10} = 30\%$	$P = x\ 100\% \frac{4}{10} = 40\%$	$P = x\ 100\% \frac{3}{10} = 30\%$	$P = x\ 100\% \frac{0}{10} = 0\%$

To provide a comprehensive visual overview, the following figures illustrate the sequential stages of the research process—from material preparation to the final ecoprint outcome.

Table 1 presents the average color brightness levels for each fixation duration. The 10-minute treatment resulted in slightly brighter hues, whereas the 30- and 60-minute treatments showed darker but still acceptable shades.

In terms of motif clarity, the 30-minute fixation produced the most distinct and well-defined leaf patterns, while both shorter and longer times yielded slightly blurred outlines. The moderate fixation time allowed sufficient pigment transfer without excessive oxidation.

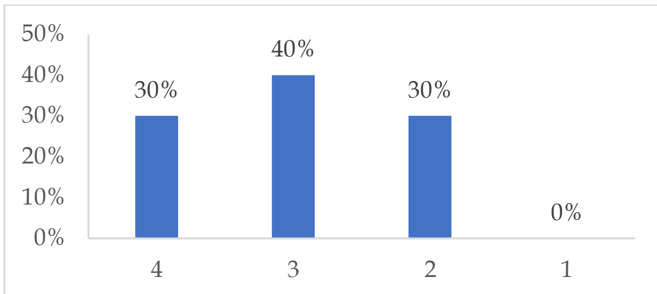

Figure 4. Color brightness histogram over a 10-minute period

Table 2. Presents the Distribution of Color Brightness Scores for the 30-Minute Fixation Treatment

Assessment Aspects	Assessment Score			
	4	3	2	1
Color Brightness	$P = x\ 100\% \frac{3}{10} = 30\%$	$P = x\ 100\% \frac{3}{10} = 30\%$	$P = x\ 100\% \frac{3}{10} = 30\%$	$P = x\ 100\% \frac{1}{10} = 10\%$

Based on Table 2, it is observed that at the 30-minute fixation duration, 3 ecoprint samples (30%) received a score of 4 (*very appropriate*), 3 samples (30%) scored 3 (*appropriate*), 3 samples (30%) scored 2 (*less appropriate*), and 1 sample (10%) scored 1 (*inappropriate*). These data indicate that most of the ecoprint samples at 30-minute fixation show balanced color brightness levels with a tendency toward moderate tone depth.

Figure 5 illustrates the color brightness histogram over the 30-minute fixation period. The histogram shows relatively stable brightness across samples, with a slight tendency toward darker hues compared to the 10-minute treatment, but overall still within acceptable visual standards.

The cleanliness of the ecoprint surface varied slightly across treatments. Samples fixed for 10 and 30 minutes appeared cleaner and more even in tone, while the 60-minute sample displayed faint dark spots likely caused by oxidation of iron ions.

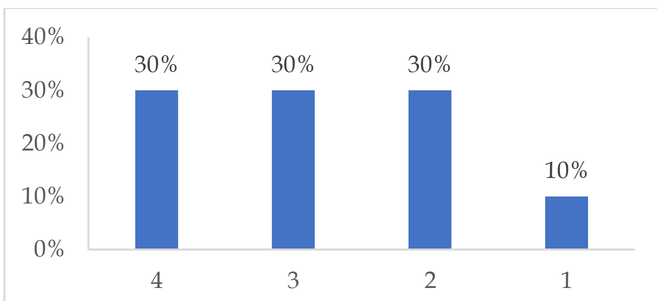

Figure 5. Color Brightness Histogram over a 30-minute period

Table 3. Analyzing Color Brightness

Assessment Aspects	Assessment Score			
	4	3	2	1
Color Brightness	$P = x\ 100\% \frac{1}{10} = 10\%$	$P = x\ 100\% \frac{6}{10} = 60\%$	$P = x\ 100\% \frac{2}{10} = 20\%$	$P = x\ 100\% \frac{1}{10} = 10\%$

Based on table 3, it is known that the observation data for a period of 60 minutes, 1 ecoprint obtained a score of 4 (very appropriate) with a percentage of 10%, 6 ecoprints obtained a score of 3 (appropriate) with a percentage of 60%, 2 ecoprints obtained a score of 2 (not appropriate) with a percentage of 20%, and 1 ecoprint obtained a score of 1 (very inappropriate) with a percentage of 10%. From the results of the data can be seen in the following graph:

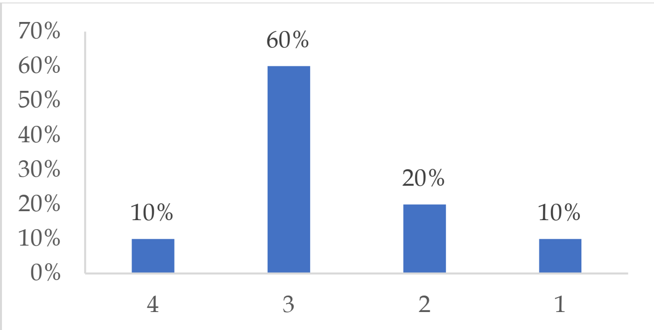

Figure 6. Color brightness histogram over a period of 60 minutes

Overall, quantitative observations indicated that all three fixation times produced satisfactory ecoprint results. The 30-minute treatment yielded the best balance between color brightness, motif clarity, and cleanliness.

Discussion

The consistent reddish-purple coloration across treatments can be explained by the chemical interaction between the tannin and anthocyanin compounds in young teak leaves and the ferrous ions (Fe^{2+}) in tunjung solution. This interaction forms a metal–tannin complex, which is chemically stable and imparts deep, lasting color to the fabric (Alegbe et al., 2024; Kaur & Chopra, 2023). This finding aligns with the results of Kurniawidi (2023), who demonstrated that teak leaf pigments contain anthocyanins that react effectively with ferrous ions to produce a reddish-brown hue with good color fastness. Because the concentration of tunjung was identical for all treatments, variations in fixation time did not significantly alter the chemical bonding process or the resulting hue (Negi, 2025).

Differences in motif clarity and cleanliness are primarily attributed to oxidation and diffusion dynamics occurring during the steaming and post-fixation drying stages rather than during the fixation period itself. Short fixation times may result in incomplete coordination between ferrous ions and pigment molecules, leading to weaker color bonding and less defined motifs (Muruganandham et al., 2023). A similar observation was reported by Astuti et al. (2023), who analyzed ecoprint wastewater in small batik industries and noted that excessive metal ion residues can affect color uniformity and motif definition due to oxidation imbalance. In contrast, extended total processing time—including steaming and exposure to air—can promote gradual oxidation of ferrous (Fe^{2+}) to ferric (Fe^{3+}) ions, resulting in slightly darker and less uniform surface coloration (Dey, 2025; Fadhilah, 2025). Royhan (2025) also emphasized that prolonged fixation enhances ion diffusion, influencing fiber porosity and the sharpness of printed motifs.

Furthermore, the artificial fiber used (ruby silk), which lacks abundant hydroxyl groups, limits the formation of stable dye–fiber bonds compared to natural fibers such as cotton or silk (Baaka et al., 2023). This result is consistent with findings by Artati (2025), where natural dye sensitization using plant extracts showed reduced bond formation on synthetic fibers compared to natural ones due to the absence of reactive hydroxyl sites. Similarly, Purwanto (2024) found that eco-dyeing with local leaves on synthetic fabrics required surface modification to improve color adhesion. This characteristic explains the minimal quantitative variation among treatments despite visible qualitative differences.

From an educational standpoint, this study provides a valuable example of contextual science learning in which students can explore the relationship between natural materials and chemical principles (Setianingrum, 2023). The ecoprint process demonstrates key concepts in chemical reactions (complexation and oxidation), diffusion, and environmental sustainability. It can serve as a project-based learning (PBL) activity integrating chemistry, biology, and environmental science (Fuad et al., 2024; Royhan, 2025). According to Abubakar (2024), the implementation of ecoprint training for local communities can serve as a bridge between vocational education and sustainable entrepreneurship, enhancing creativity and environmental literacy. Purwanto (2024) also suggested that empowering housewives through ecoprint workshops can improve both social and economic aspects while preserving local ecological knowledge. Sastriwijaya (2025) emphasized that renewable-based colouring materials, such as sappanwood extract, can also be integrated into science learning as an example of green technology innovation.

These educational integrations illustrate how contextual learning in textile design contributes to developing students' competencies in environmental science and local cultural appreciation (Jariah, 2023). Through such programs, the use of natural dyes becomes more than an artistic process—it evolves into a medium of scientific exploration and community empowerment (Astuti et al., 2023; Royhan, 2025). Thus, this study demonstrates that ecoprinting using teak leaves and tunjung mordant not only supports sustainable textile practices but also strengthens the link between science, culture, and education within the vocational fashion field.

Conclusion

The study found that varying the fixation duration using tunjung (ferrous sulfate) at 10, 30, and 60 minutes did not significantly affect the color brightness or motif quality of ecoprint fabrics dyed with young teak leaves on artificial silk. All treatments produced similar reddish-purple hues characteristic of teak leaf pigments. Among the treatments, a 30-minute fixation provided a visually balanced result in terms of color uniformity and motif clarity, which can serve as a practical recommendation for ecoprint applications under similar conditions.

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The authors declare no conflict of interest. All authors have read and agreed to the published version of the manuscript.

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