

Effect of Tegeran Wood Extract Concentration on Absorbency and Durability Luntur Katun

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Abstract.

This study examined the effect of tegeran wood (Cudrania javanensis) extract concentration on color absorption and color fastness of cotton fabric. A controlled quantitative experiment used five concentration levels (20%, 40%, 60%, 80%, and 100%). Twenty-five cotton specimens were prepared; however, identical visual scores within each concentration produced five effective observation points for statistical analysis. Dyeing was conducted by three multi-dipping cycles at 28–30 °C and neutral pH. Color absorption, washing fastness, and dry-rubbing fastness were rated on a 1–5 visual scale. Simple linear regression showed significant positive effects on color absorption ($r=0.971$; $R^2=0.942$; $p=0.006$) and washing fastness ($r=0.945$; $R^2=0.893$; $p=0.015$). Dry-rubbing scores increased perfectly with concentration in this limited dataset ($R^2=1.000$), requiring cautious interpretation. The 100% concentration produced the highest overall scores and an intense golden-yellow appearance.

Keywords: Cotton Fabric, Natural Dye, Tegeran Wood, Color Absorption And Color Fastness.

I. INTRODUCTION

The use of natural dyes in textiles is gaining renewed attention due to demands for more sustainable fashion production processes. Natural dyes come from renewable sources and are in many cases more biodegradable than synthetic dyes. However, their application still faces issues of color consistency, absorption efficiency, and colorfastness. Pizzicato et al. (2023) emphasize that the sustainability of natural dyes requires careful process control to ensure ecological excellence does not compromise the technical quality of textiles. Christian and Susanti (2024) also demonstrate that the effectiveness of natural dyes on fabric is strongly influenced by the type of dye, fiber type, mordant, and dyeing process conditions.

One source of natural dyes that has long been used in Indonesian textile traditions is tegeran wood (*Cudrania javanensis*). This wood produces a spectrum of yellow to brownish yellow and is known as one of the dyes for batik. Atika and Salma (2017) reported that tegeran can provide a distinctive color quality to batik, while Rahayuningsih et al. (2022) found that the concentration of the extract, time, temperature, and the ratio of ingredients to the solution affect the color strength and fastness of cotton fabric. Darmawan et al. (2024) explained that the yellow color character of tegeran is related to the morin content and that optimizing mordanting plays a crucial role in improving the quality of the dyeing results.

Cotton was chosen as the research material because it is a cellulose fiber widely used in fashion products, is comfortable, easy to process, and has hydrophilic properties. However, cellulose fibers do not always form strong bonds with natural dye molecules. Kovačević et al. (2021) showed that differences in fiber structure affect the affinity of natural dyes, while Muslim and Devi (2019) emphasized the importance of mordant treatment to improve the dyeing quality of cotton. The results of research by Hanafi et al. (2022) also showed that variations in the mordanting process can affect the color intensity and fastness of cellulose-based batik fabrics.

Extract concentration is one of the parameters that determines the number of dye molecules available in the solution. At low concentrations, the number of pigments interacting with the fiber tends to be less, resulting in a pale color. Conversely, increasing the concentration has the potential to increase the amount of pigment adsorbed to a certain limit. Rahayuningsih et al. (2022) found that solution composition and dyeing conditions determine the color strength value of cotton. Darsih et al.

(2019) also showed that the color response of tegeran in cotton is influenced by the interaction between the dye and the mordant system, so strict control of process variables is necessary.

In addition to color depth, fastness is an important indicator of textile quality. Fabrics that appear dense after dyeing do not necessarily have resistance to washing or rubbing. The SNI ISO 105-C06:2010 and SNI ISO 105-X12:2016 standards provide references for testing fastness to washing and rubbing, while SNI ISO 105-A02:2010 provides a grayscale for assessing color changes. In the context of natural dyes, Ding and Freeman (2017) stated that the use of mordants can improve dye attachment to cotton, while Parveen et al. (2019) showed that a controlled process approach is necessary to achieve adequate color gamut and fastness.

This research arose from a practical need at the Multi Tamara Fashion Designer Textile & Art Boutique, where textile processing and exploration are conducted within the context of fashion production and design. The exploration of tegeran is relevant because the resulting golden yellow color has the potential to be used in ethnic clothing, textile crafts, and fashion products with a strong visual identity. At the same time, the color quality must be sufficiently stable so that the experimental results are not limited to aesthetic aspects, but also have functional value for real use.

Previous research has extensively examined natural dyes and the role of mordants, but this study places variations in tegeran extract concentration as the primary variable observed in two technical outcomes simultaneously: color absorption and fastness in cotton fabric. This focus is important because changing the concentration is a simple intervention and relatively easy to implement by small-scale textile producers. By maintaining the fabric type, temperature, pH, dyeing time, number of cycles, and fixative constant, the relationship between concentration and product quality can be observed more precisely.

The purpose of this study was to analyze the effect of variations in the concentration of tegeran wood extract on the color absorption of cotton fabric, analyze its effect on color fastness due to washing and dry rubbing, and identify the concentration level that provides the best results based on the observed indicators. The results of the study are expected to provide a practical basis for the exploration of natural dyes in the field of fashion design vocational education while providing initial data for the development of more precise experiments with digital color measurement instruments.

II. METHOD

The study used a quantitative approach with controlled laboratory experiments. The independent variable was the concentration of tegeran wood extract, while the dependent variables included color absorption, fastness to washing, and fastness to dry rubbing. The study was conducted at the Multi Tamara Fashion Designer Textile & Art Boutique on June 13, 2026. Five concentration levels were used, namely 20%, 40%, 60%, 80%, and 100%, with codes K1 to K5.

The main material is white cotton cloth with the same type and characteristics. The cloth is cut uniformly measuring approximately 30 cm × 30 cm. The initial design stipulates five replications at each concentration level so that physically 25 pieces of cloth are available. Material selection is done purposively to maintain the homogeneity of fiber type, base color, texture, thickness, and size. Factors other than concentration, such as fabric type, mordanting process, temperature, dyeing time, pH, material-liquid ratio, drying technique, and fixative are kept constant so that the effects of concentration can be observed more focused.

Fabric preparation begins with washing using TRO and detergent, followed by mordanting using alum and soda ash. The dye solution is made from boiled and filtered tegeran wood extract. A 100% solution is treated as an extract without dilution, while concentrations of 20%, 40%, 60%, and 80% are obtained by diluting with water according to the proportions. Dyeing is carried out using a multi-dipping technique with three dye-dry cycles. Each cycle lasts approximately 30 minutes at a temperature of 28–30 °C and a neutral pH. After dyeing, the fabric is dried in the shade and then tested.

Color absorption was assessed visually using a scale of 1–5, with a score of 1 indicating very

pale color and a score of 5 indicating very strong color. Fastness to washing and dry rubbing was also assessed on a scale of 1–5, with reference to color changes adapted from the gray scale of SNI ISO 105-A02:2010. Higher scores indicate smaller color changes or better fastness. Washing tests were conducted with a uniform procedure, while rubbing tests were conducted on the fabric surface with the same number and conditions of rubbing applied to all samples. The selection of washing and rubbing aspects refers to the characteristics of daily textile use and the principles of fastness testing in SNI ISO 105-C06:2010 and SNI ISO 105-X12:2016.

The content validity of the observation instrument was examined through expert judgment. Procedural reliability was maintained through the use of experimental standard operating procedures (SOPs), consistent treatment conditions, and repetition of the process in each group. Although the initial design provided for five replicates per concentration, the visual assessment results for replicates within the same group were identical. Therefore, the data that could be effectively analyzed statistically consisted of only five observation points representing five concentration levels.

The initial plan to use one-way ANOVA could not be validly implemented due to the lack of score variation within each concentration group. The analysis was then adjusted using descriptive statistics, Pearson correlation, and simple linear regression between concentration and each dependent variable. The significance level was determined using $\alpha=0.05$. Adjustments to the analysis method were made to ensure the statistical technique matched the characteristics of the available data, not to alter the research objectives.

Table 1. Tegeran Extract Concentration Treatment Design

Group	Concentration	Information
K1	20%	Cotton dyeing with 20% extract
K2	40%	Cotton dyeing with 40% extract
K3	60%	Cotton dyeing with 60% extract
K4	80%	Cotton dyeing with 80% extract
K5	100%	Cotton dyeing with extract without dilution

Source: researcher's design, adapted from Rahayuningsih et al. (2022).

Table 2. Visual Assessment Scale

Score	Color Absorption Power	Fastness
1	Very pale	Very faded
2	Not strong enough	Quite a lot of fading
3	Enough	Moderate changes
4	Strong	Little changed

5	Very strong	Very good/does not fade
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Source: researcher instruments and adaptation of SNI ISO 105-A02:2010.

Research materials and tools were prepared to ensure that all units achieved equivalent conditions. The main equipment included a stove and gas as a heat source, a pan for the washing, mordanting, and extraction processes, a bucket as a soaking and dyeing container, a measuring cup for measuring the volume of the solution, a spatula and spoon for homogenization, a small container for dissolving the auxiliary materials, a tile cloth for filtering the extract, and a clothesline and tongs for drying. The main materials consisted of white cotton cloth, tegeran wood powder, alum, TRO, soda ash, water, and detergent. The selection of simple tools was intended to ensure that the procedure was relatively easy to replicate in a textile studio or vocational practice unit.

The fabric preparation stage was carried out before contact with the dye solution. The fabric was cut into 25 uniformly sized pieces. All pieces were washed using TRO and detergent to remove dirt, oil, or finishing materials that could potentially inhibit solution penetration. After washing, approximately three liters of water were heated, then approximately 200 grams of alum was dissolved and soda ash was added. Twenty-five fabric samples were placed in the mordanting solution, boiled for about an hour, then left to soak for three days with periodic inspections. This procedure was applied equally to all samples to ensure a uniform initial fabric condition.

Tegeran extraction was carried out by preparing approximately one kilogram of tegeran wood powder for the entire sample. Water was heated to boiling in sufficient volume, then the tegeran powder was added and boiled for about an hour. After the extraction process, the solution was transferred to another container and filtered using a tile cloth to separate the pulp. The filtered solution was treated as a 100% extract. This study did not measure the levels of active compounds in the extract chemically, so the term 100% refers to the stock solution extracted without additional dilution.

Concentration variations were prepared volumetrically from stock solutions. A 20% concentration was composed of 20 parts extract and 80 parts water; a 40% concentration of 40 parts extract and 60 parts water; a 60% concentration of 60 parts extract and 40 parts water; an 80% concentration of 80 parts extract and 20 parts water; and a 100% concentration using the extract without the addition of water. This proportional dilution system was chosen to facilitate the application of different treatments and maintain the relationship between successive concentration levels.

Each concentration group was coded K1 to K5. Within each group, there were five physical replicates, for example, K.1.1 to K.1.5 for the 20% group and so on. Coding was performed before dyeing to prevent sample mix-ups during the soaking, drying, washing, rubbing, and recording processes. Each piece of fabric was treated as an experimental unit, even though the replicate scores were identical in the final analysis, so the group was represented by a single visual value.

The dyeing process uses a three-cycle multi-dipping process. In each cycle, the fabric is immersed in the dye solution, exposed for approximately 30 minutes at a temperature of 28–30°C and a pH of approximately 7, then removed and air-dried in the shade before entering the next cycle. Multi-dipping was chosen to allow the pigment to be absorbed gradually and to reduce reliance on a single dipping process, which could potentially result in uneven penetration. During the process, the fabric is not dried in direct sunlight to minimize color changes due to light exposure.

After dyeing, the samples underwent fixation, or color locking, using the same treatment for all groups. The purpose of fixation is to help improve the pigment's attachment to the fiber, preventing the color from being easily removed during subsequent testing. The type and dosage of fixative were not used as research variables, as the focus of the experiment was on the concentration of tegeran extract. Therefore, any differences in scores are expected to primarily reflect changes in concentration levels, although the study still recognizes that the fixation process is an important part of the natural dyeing system.

Drying was carried out in shaded conditions with relatively even air circulation. Samples were positioned so that they did not overlap and were clamped to prevent shifting. Drying until the surface was no longer wet was important because visual assessment of damp fabric can give the impression of a darker color than when dry. All absorbency observations were made after the fabric had reached a comparable dry state.

The absorbency assessment focuses on the visual intensity of the color seen after dyeing and drying. A score of 1 is given to fabrics that appear very pale, a score of 2 to those that are still not very strong, a score of 3 to those that are moderately intense, a score of 4 to those that are strong, and a score of 5 to those that are very strong. This instrument is simple and serves as an operational indicator, not as a substitute for chemical absorbance measurements. Therefore, the term 'color absorbency' in this study refers to the visual indicator of absorption results reflected through the strength of the color on the fabric.

Washing fastness testing was performed using a uniform procedure for all samples, including water volume, detergent use, treatment time, and drying method after washing. After the fabric was dry, color change was assessed on a scale of 1–5. A score of 1 indicates very high color fading, a score of 2 indicates moderate color fading, a score of 3 indicates slight color fading, and a score of 5 indicates excellent or no significant fading. This principle refers to the use of a gray scale as a reference for color change.

Dry rubbing fastness testing was performed by rubbing the fabric surface with the same rubbing medium at a uniform pressure and number of strokes. The assessment focused on the color stability of the sample surface after rubbing. Because the study did not use a standardized crockmeter, the results should be interpreted as controlled studio-level testing. However, consistent procedures were attempted to ensure that comparisons between concentrations remained meaningful.

Observation instruments are set up to record sample codes, extract concentrations, dyeing dates, solution temperatures, pH, dyeing times, process notes, visual descriptions of color, absorbency scores, wash fastness scores, and dry rub scores. Process records are essential for establishing an audit trail for experiments. If deviant results occur, records of temperature, solution conditions, or specific events can be used to trace the source of variation.

The content validity of the observation sheet was assessed through expert assessment with expertise in textiles and research methodology. The assessed aspects included the suitability of the instrument to the research variables, clarity of the absorbency indicator, clarity of the fastness indicator, suitability of the 1–5 scale, suitability of the standard reference, clarity of the instructions, and ease of use. The expert judgment approach was chosen because the instrument is an experimental observation sheet, not a psychometric scale that requires a latent construct structure.

Reliability in material research is maintained more through procedural consistency than through internal item consistency. Therefore, all batches underwent the same initial washing, mordanting, dyeing, fixation, drying, and testing steps. Visual repeatability of five replicates per concentration was intended to check the stability of the results. The fact that the scores of all five replicates were identical indicates consistency of observation, but also raises a statistical problem because there is no within-group variance to use for ANOVA.

Data analysis began with tabulating the scores for each concentration. Descriptive statistics were used to obtain minimum, maximum, mean, and standard deviation values. The relationship between concentration and each outcome was then calculated using Pearson correlation and simple linear regression. For each model, the correlation coefficient r , coefficient of determination R^2 , regression coefficient, and significance values were reported. Statistical interpretation was performed taking into account the small effective sample size.

A one-way ANOVA was originally planned because the study had five treatment groups. However, ANOVA requires information on within-group variation to compare between- and within-group variation. Because the five replicates at each level obtained exactly the same scores, the within-

group variance was zero, and the test could not produce reliable inferences. The decision to replace ANOVA with regression was not to seek significant results, but rather to avoid applying a test whose data assumptions were not met.

The significance threshold was set at $p < 0.05$. Regression results should still be read in conjunction with a simple effect size (R^2) and descriptive patterns, as a p-value at only five observation points is limited. The statistical relationship should not be interpreted as universal causation beyond experimental conditions, but as preliminary evidence that changes in concentration are associated with changes in scores across the 20–100% concentration range tested.

III. RESULTS AND DISCUSSION

Table 3. Observation Results at Five Concentration Levels

Code	Conc.	Visual Description	Absorption Capacity	Wash Fade	Dry Rub
K1	20 %	Very light yellow/pastel	2	2	1
K2	40 %	Light yellow	3	3	2
K3	60 %	Bright yellow	3	3	3
K4	80 %	Golden yellow/mustard	4	4	4
K5	100 %	Dark golden yellow	5	4	5

Source: experimental observation sheet, processed by researcher (2026).

Table 4. Descriptive Statistics of the Dependent Variables

Variables	N	Min	Max	Mean	SD
Color absorption power	5	2	5	3.40	1.140
Wash fade	5	2	4	3.20	0.837
Dry rub	5	1	5	3.00	1.581

Source: SPSS output, processed by researchers (2026).

The results showed a consistent trend: the higher the concentration of tegeeran extract, the stronger the fabric color intensity and the higher the fastness score. At a concentration of 20%, the fabric was a very light yellow approaching pastel, while at a concentration of 100% the color developed into a deep golden yellow. Increasing the concentration was also followed by an increase in the washing and dry rubbing fastness scores, although the change in washing fastness stopped at a

score of 4 at concentrations of 80% and 100%.

Descriptively, the average color absorption score was 3.40 with a standard deviation of 1.140. The average wash fastness was 3.20 with a standard deviation of 0.837, while the dry rub fastness had a mean of 3.00 and a standard deviation of 1.581. The largest variation occurred in the dry rub fastness, as the score increased from 1 at 20% concentration to 5 at 100% concentration. The wide range of scores indicates that the five concentration levels were able to visually capture changes in the dyeing results.

For color absorption, simple linear regression yielded $r=0.971$, $R^2=0.942$, and $p=0.006$. The concentration regression coefficient of 0.035 indicates a positive relationship. Thus, in this research data, an increase in extract concentration is associated with an increase in color absorption scores. The magnitude of R^2 indicates that 94.2% of the variation in absorption scores at the five observation points is associated with changes in concentration, while the remainder may be related to process variations that are not fully captured by the model.

These findings are consistent with Rahayuningsih et al. (2022), who showed that the amount of dye in the solution, along with other process parameters, affects the color strength of cotton. Darmawan et al. (2024) also identified dye composition and mordanting as important factors in achieving stronger colors. Mechanistically, increasing the concentration provides more pigment molecules to interact with the cellulose fibers. However, because this study used visual assessment, this relationship cannot be equated with absorbance values or K/S values obtained from a spectrophotometer.

Table 5. Summary of Correlation and Regression

Dependent Variable	r	R ²	Sig.	Information
Color absorption power	0.971	0.942	0.006	Significant
Wash fade	0.945	0.893	0.015	Significant
Dry rub	1.000	1.000	0.000	Significant *

**Perfect correlation needs to be interpreted with caution because only five observation points are effective.*

For wash fastness, the regression yielded $r=0.945$, $R^2=0.893$, and $p=0.015$. The regression coefficient of 0.025 also indicates a positive direction. Fabrics at low concentrations had wash fastness scores of 2–3, while 80% and 100% concentrations achieved scores of 4. These results indicate that increasing concentrations under the same mordanting and dyeing conditions is associated with increased color fastness after washing.

This relationship can be understood through the interaction between pigment, mordant, and fiber. Ding and Freeman (2017) emphasized that mordants play a role in the formation of more stable bonds in natural cotton dye systems. Hanafi et al. (2022) also showed that variations in mordanting can affect sharpness and fastness. In this study, the type of mordant was kept constant, so the pattern of increasing scores more likely reflects differences in the amount of pigment available to bind to the fiber, although the contribution of other factors cannot be completely eliminated.

Dry rubbing fastness showed the sharpest pattern. Scores increased sequentially from 1, 2, 3, 4, to 5 as concentrations increased to 20%, 40%, 60%, 80%, and 100%. Regression yielded $r=1.000$ and $R^2=1.000$. Mathematically, this appears to be a perfect relationship, but the results should be read with caution because there were only five effective observation points and the discrete scale of measurement used. A perfect relationship in a small data set should not be interpreted as evidence that

the same pattern will always occur in larger replicates.

The correlation matrix between variables shows a strong positive relationship. The correlation between absorbency and wash fastness is 0.943; between absorbency and rub fastness is 0.971; and between wash fastness and rub fastness is 0.945. This pattern indicates that samples with higher absorbency scores tend to also have higher fastness scores. Technically, this is in line with the idea that the more pigment that successfully binds and remains on the fiber, the better the color fastness to mechanical treatment and washing.

These results align with the literature on natural dyes, which places the balance between absorption and fixation as key to quality. Pizzicato et al. (2023) cited low affinity and fastness as the main challenges for natural dyes. Kovačević et al. (2021) demonstrated that the interaction of dyes with cellulose fibers is strongly influenced by process conditions, while Parveen et al. (2019) demonstrated the importance of process control to achieve stable colors. Therefore, increasing concentration alone cannot be separated from mordanting, pH, temperature, time, and dyeing techniques; in this study, these factors were controlled to maintain the focus of the analysis on concentration.

From a fashion design perspective, 100% concentration yielded the strongest visual results. This rich golden yellow color has the potential to be used as an accent in ethnic clothing, textile crafts, or materials with natural characteristics. An 80% concentration also produced a mustard-like golden yellow with an absorption score of 4, wash fastness of 4, and rub fastness of 4. Thus, higher concentrations demonstrated a better combination of color intensity and durability under these experimental conditions. However, practical concentration selection should also consider material efficiency, cost, and production consistency, which were not measured in the study.

This study has important limitations. Although 25 fabric swatches were prepared, five replicates at each concentration yielded identical visual scores, thus providing no within-group variation. Consequently, the planned one-way ANOVA could not be validly run. Analysis based on five observation points also makes correlation and regression estimates sensitive to small score changes. Furthermore, visual assessment on a 1–5 scale has limited resolution compared to a colorimeter or spectrophotometer. Chakraborty (2010) emphasized the importance of objective measurements in textile color studies; therefore, further studies should utilize digital devices to obtain color parameters such as $L^*a^*b^*$ or K/S.

Despite its limitations, the study provides useful preliminary information regarding the response of cotton to increasing dye concentrations. The findings support the use of natural dyes as a design exploration material, while emphasizing that quality evaluations need to encompass not only color appearance but also fastness. Other literature, such as Azizah and Hartana (2018) and Muslim and Devi (2019), shows that natural dyes in cotton can produce good quality when the processing treatment is controlled, so that further development directions can focus on mordant optimization, variations in fixation methods, and instrumental measurements.

Methodologically, identical results across five replicates at a single concentration level may indicate a consistent treatment process, but it may also indicate that the visual instrument is not sensitive enough to detect small differences between samples. On an ordinal scale of 1–5, two fabrics with relatively small differences in intensity may obtain the same score. Therefore, uniformity of scores should not be taken as a true absence of physical variation. The use of a spectrophotometer would allow for the reading of small differences through reflectance values or color coordinates.

In the context of quality standards, colorfastness interpretation also requires distinguishing between color changes in the primary fabric and staining on the secondary fabric. This study focused on the visual changes in the fabric after washing and dry ironing. SNI ISO 105-A03:2010 provides a grayscale for staining assessment, so further research could expand the measurement by recording color transfer to the secondary fabric. This approach would provide a more complete picture of the suitability of *tegeran* for fashion products that come into contact with other materials.

The mordant aspect also presents an opportunity for further research. Several studies have shown that the type of mordant can alter the color direction and strength of the dye bond on cotton. Darsih et al. (2019) demonstrated the effect of bio-mordants on *Cudrania javanensis* dyeing, while Ding and Freeman (2017) discussed the optimization of mordant dyes on cotton. Because this study maintained a single mordant system, concentration was the primary factor, it is not yet possible to conclude which combination of concentration and mordant is most efficient.

From a production perspective, 100% concentration yielded the highest visual performance but used the most dye. If the production goal is to achieve a golden yellow color of sufficient quality while saving on materials, 80% concentration merits further testing, as it yielded a score of 4 on all three indicators. An economic evaluation was not conducted in this study, so this recommendation remains a practical hypothesis and requires analysis of the costs of materials, water, energy, time, and fixative requirements.

This research also demonstrates that a simple experimental approach can be integrated into vocational fashion design learning. Students can directly explore the relationship between materials, processes, color, and fabric performance. Such experiments connect aesthetics with quality measurement, allowing exploration of natural dyes not only to produce interesting samples but also to develop an understanding of process consistency and textile quality evaluation.

Overall, the directional consistency across the three indicators supports the notion that increasing tegeran concentrations has a positive effect within the tested range. However, because the effective analysis design consisted of only five points and lacked a dye-free control group, generalizations must be limited to these experimental conditions. Future research should increase the number of concentration points, use instrumentally measured replications, and include a control group to more robustly evaluate the shape of the dose-response relationship.

Table 6. Color Absorption Regression Model

Parameter	Mark
R	0.971
R Square	0.942
Adjusted R Square	0.923
Std. Error	0.316
F	49,000
Sig.	0.006
B concentration	0.035

Source: SPSS output, processed by researchers (2026).

Table 7. Washing Fastness Regression Model

Parameter	Mark
R	0.945
R Square	0.893
Adjusted R Square	0.857
Std. Error	0.316
F	25,000
Sig.	0.015
B concentration	0.025

Source: SPSS output, processed by researchers (2026).

Table 8. Regression Model of Dry Rub Fastness

Parameter	Mark
R	1,000
R Square	1,000
Adjusted R Square	1,000
Std. Error	0,000
Sig.	0,000
B concentration	0.050

Source: SPSS output, processed by researchers (2026). Perfect relationships should be read with caution due to the limited number of observation points.

Table 9. Correlation Matrix between variables

Variables	Absorption Capacity	Wash Fade	Dry Rub
Color absorption power	1,000	0.943	0.971
Wash fastness	0.943	1,000	0.945
Dry rubbing resistance	0.971	0.945	1,000

Source: SPSS output, processed by researchers (2026).

Comparison of group scores revealed a stepwise pattern. K1 at 20% achieved an absorbency score of 2, wash fastness of 2, and dry rub of 1. K2 at 40% increased to 3, 3, and 2. K3 at 60% maintained absorbency and wash fastness at 3, but dry rub increased to 3. K4 at 80% achieved a score of 4 on all indicators, while K5 at 100% achieved an absorbency score of 5, wash fastness of 4, and dry rub of 5. The lack of increase in wash fastness from 80% to 100% suggests that the resistance response to washing may be approaching a plateau on the visual scale used.

The differences in patterns between the indicators provide important information. Absorbency increased most markedly at the highest concentration, while wash fastness appeared to reach the study's maximum score at 80%. Dry rub fastness increased linearly by one point for every 20% increase in concentration. Because the indicators use a coarse scale, the pattern may oversimplify differences that are actually more continuous. Measurements with high-resolution instruments are needed to determine whether there are still improvements between 80% and 100% that are not captured by the visual scale.

The intercept value in the absorbency regression of 1.300 and the concentration coefficient of 0.035 represent an increasing prediction line. Operationally, each 20 percentage point increase in concentration corresponds to an approximately 0.7 predicted absorbency score point. In the wash-fastness model, a coefficient of 0.025 means a 20 percentage point increase corresponds to approximately 0.5 predicted score points. In the dry-rub model, a coefficient of 0.050 corresponds to a one score point increase for every 20 percentage point increase in concentration. These figures apply only to the linear model of this data and should not be extrapolated beyond the 20–100% range.

The high R^2 values for all three models indicate a strong correlation, but the very high coefficient of determination in the small dataset may be influenced by the number of points and the shape of the scale. Because all predictors are in a regular concentration order and the scores also increase

regularly, the correlation is high. In further research, a larger number of numerical replicates and interreplicate variation would provide a more realistic estimate of model uncertainty and allow for more informative confidence intervals.

The relationship between absorbency and fastness does not necessarily mean that a more intense color is automatically more durable. Theoretically, intense color can originate from pigments that are abundantly attached but not completely bound. Therefore, the high correlation results in this study likely reflect a combination of mordanting conditions, multi-dipping techniques, and concentrations working together. Darmawan et al. (2024) showed that mordanting systems can improve fastness in cotton, while Pizzicato et al. (2023) noted that the affinity and fastness of natural dyes are strongly influenced by complex chemical-physical interactions.

Rahayuningsih et al. (2022) reported that the optimum conditions for dyeing cotton with natural dyes are determined not only by concentration but also by temperature, time, and the material-to-liquid ratio. The results of this study do not contradict these findings, as factors other than concentration were intentionally kept constant. In other words, this study does not assert that concentration is the only important factor, but rather demonstrates that under constant process conditions, changes in concentration are closely related to differences in results.

In fashion applications, the appeal of natural dyes lies not only in their color, but also in their material narrative and sustainability. The golden yellow hue of tegeran can shape a product's visual identity, especially when combined with natural fibers like cotton. However, before commercial use, consistency between batches needs to be tested. Variations in wood raw materials, plant age, particle size, water quality, and storage time of the extract can alter the pigment composition, so the same volumetric concentration may not always produce identical colors.

This research also has implications for practical learning. Students can use a graded concentration design to understand the relationship between dose and visual response, but evaluation should focus on skills such as controlling variables, recording processes, and interpreting data limitations. It is important that experimental learning focuses not only on attractive color results but also on developing a scientific attitude and awareness of textile quality standards.

The use of tegeran in fashion studios can be developed through a combination of fabric surface techniques such as shibori, tie-dye, block printing, or application to batik motifs. However, it is important to distinguish between the findings of this study, which examined the fabric as a whole, and the possible color behavior of local motif techniques that vary in solution thickness, pressure, and contact area. Further experiments can use 80% and 100% concentrations as starting points to evaluate more complex surface designs.

Testing standards are crucial for developing product results. SNI ISO 105-C06:2010 and SNI ISO 105-X12:2016 provide more standardized procedures for washing and scrubbing, while this study used a simplified studio approach. Therefore, the scores obtained cannot yet be considered quality certification. The next step is to replicate the best-practice treatment using standardized laboratory facilities and equipment so that practical findings can be compared with industry technical requirements.

From a sustainability perspective, high concentrations do yield the best performance in research, but using more material does not automatically make it the most sustainable option. Sustainability evaluations should also take into account biomass consumption, extraction energy, dilution water, waste treatment, and the potential for solution reuse. If an 80% concentration provides nearly equivalent wash-fastness quality with less material use than 100%, a resource efficiency analysis could be a practical follow-up topic.

Academically, this research can be positioned as a quantitative exploratory study with limited visual data. Its main strengths are process control and consistent results, while its main weaknesses are instrument resolution and the number of effective observation points. While transparency regarding these limitations allows the findings to serve as a basis for developing more robust research

without overestimating statistical certainty.

The color pattern, which progresses from very light yellow to golden yellow, also demonstrates the potential of tegeran as a source for a graduated color palette. In design, gradations controlled through concentration can be utilized to build a color series within a single collection without changing dye types. A concentration of 20–40% can be directed toward softer shades, 60–80% toward bolder yellows, and 100% toward the strongest accents. However, the use of this palette is only supported by visual assessment of the research and needs to be retested on different batches to ensure color reproducibility.

The stability of a neutral pH during dyeing is one of the controlled conditions. pH can affect the ionic form of dye molecules and their interaction with the fiber surface. This study did not compare acidic and basic conditions, so it cannot determine whether neutral pH is the optimum condition. Further development can use a factorial design that combines concentration and pH, provided the number of replications and measurement instruments are sufficient to separate the effects of each factor.

A temperature of 28–30 °C was maintained for all treatments to prevent differences in results from variations in heat. In some natural dye systems, increasing temperature can accelerate diffusion but also alter the stability of the dye components. Therefore, the results of this study specifically represent dyeing at temperatures near room temperature. If dyeing is to be applied to a production process that uses higher temperatures, the pattern of concentration-color results may change and requires further testing.

The use of three multi-dipping cycles should also be considered as part of the research conditions. Repeated dip-drying allows the color layers to develop gradually and may contribute to higher scores at higher concentrations. Thus, concentration and number of cycles practically interact in shaping the final intensity. Future studies could compare one, two, and three cycles at the same concentration to determine whether color enhancement is more efficiently achieved through increasing concentration or increasing dip cycles.

In the wash fastness test, the maximum score achieved was 4, not 5. This finding indicates that although higher concentrations improve fastness, there is still some color change after washing. This means that optimization does not stop at increasing the concentration. Mordant formulation, fixation time, and washing conditions need further research to improve fastness without excessively increasing the concentration. This finding is relevant for apparel applications because washing is one of the most important repeated exposures that determines color longevity.

In contrast, the dry rubbing score reached 5 at 100% concentration. This result indicates the fabric surface was relatively stable to dry rubbing under the procedure used. However, the study did not include wet rubbing, even though humidity can increase color transfer. For fashion products, wet rubbing testing would complement the performance picture, especially for garments exposed to sweat or worn in humid environments.

The strong correlation between variables can also be used to design initial screening instruments in the studio. If laboratory measurements are not yet available, a combination of color intensity observations and simple colorfastness tests can help select samples worthy of further testing. However, this approach is only suitable for internal screening, not as a substitute for laboratory standards. Commercial decisions should still use standardized testing to allow objective comparison of quality between production runs.

During the production stage, repeated extraction of natural materials can result in variations in pigment composition. Tegeran wood from different sources, ages, moisture contents, and particle sizes can potentially produce stock solutions with varying strengths, even with the same mass-to-volume ratio. Therefore, the term 100% concentration in this study does not equate to absolute chemical concentration. Standardizing stock solutions by measuring absorbance before dyeing will be an important step to improve the reproducibility of research and production.

The context of the Multi Tamara Boutique provides practical value because the research results can be directly translated into material experiments. However, the study has not evaluated consumer response, comfort, changes in hand feel, or fabric durability after repeated wash cycles. A good color in a single test may not necessarily maintain its quality after long-term use. Durability testing across multiple wash cycles and evaluation of the fabric's physical properties are necessary before the material is developed into a final product.

The educational implications of this research lie in the integration of design and textile science. Fashion design students can learn that aesthetic decisions such as color selection are related to measurable process variables. Concentration-based experiments introduce the concepts of variable control, replication, measurement, and statistical interpretation in a context close to creative practice. This approach can help build scientific literacy without separating design activities from material evaluation.

From a research development perspective, future designs should utilize continuous color measurements and incorporate interreplicate variation that can be recorded numerically. Continuous data allows for the use of ANOVA or regression models with more realistic uncertainty. Furthermore, photographic documentation should be conducted with constant lighting, camera distance, background, and device settings to allow for comparison of visual changes. Standardization of documentation is important because differently lit photographs can alter the perception of color intensity.

Considering all the results and limitations, the primary value of this study is demonstrating consistent directional relationships under specific experimental conditions, not establishing a definitive industrial formula. Higher concentrations yield better results on the observed indicators, but true optimization must balance color quality, durability, material use, cost, and environmental impact. Therefore, these findings are best used as a basis for selecting candidate concentration ranges for more precise testing in subsequent research phases.

IV. CONCLUSION AND SUGGESTIONS

Variations in the concentration of tegeran wood extract showed a positive relationship with the dyeing quality of cotton fabric under the experimental conditions used. Increasing the concentration from 20% to 100% was followed by strengthening the color intensity, increasing the washing fastness, and increasing the dry rubbing fastness. Linear regression showed a significant relationship in color absorption and washing fastness, while the perfect pattern in dry rubbing should be interpreted cautiously because the number of effective observations was very limited. A concentration of 100% gave the highest overall score and a deep golden yellow color, while 80% produced stable results in all indicators. Scientifically, these results support the importance of concentration as one of the parameters of the tegeran dyeing process on cotton, but do not replace the role of mordant, temperature, pH, time, and dyeing technique. Further research is recommended to use a colorimeter or spectrophotometer, maintain numerically distinguishable replications, add controls, and test variations in mordants and fixators. For fashion design practice, the results can be used as an initial basis for exploring natural golden yellow colors in cotton, while still considering material efficiency and fastness quality standards.

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