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Fabrication of fine particle powder from Teak (Tectona Grandis) leaves as a textile dyeing with environmentally friendly technology

Arif Budianto[1], Diah L. Dewi[1], Susi Rahayu[1*], Dian W. Kurniawidi[1], Halil Akhyar[2], Alfina T. Alaydrus[1]

[1]Physics Departement, Faculty of Mathematics and Natural Sciences, University of Mataram, Mataram, NTB, Indonesia
[2]Informatics Engineering Departement, Faculty of Engineering, University of Mataram, Mataram, NTB, Indonesia
*Correspondence: susirahayu@unram.ac.id

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Abstract

Green technology for eco-friendly dyes in textile industries has been required in recent decades. An innovation was established by producing textile dyes from natural sources. This research aims to identify fine particle powder's characteristics and analyze the color changes applied to the textile. The mechanical thermal was utilized to produce natural dyes. Three main stages were conducted to obtain dye powder: mordant, coloring, and fixation. The dye powder was examined for water content, phytochemical tests, FTIR, SEM-EDX, and color using the Android-based Color Analyzer and Color Grab applications. The results show that the water content of 7.21% meets the SNI 01-3709-1995 standard. So, the powder can be stored for a long time because it does not quickly spoil. In addition, the phytochemical test resulted in alkaloids, flavonoids, and tannins. This revealed that teak leaf powder can be a suitable textile dye. After that, SEM-EDX examination illustrated that the powder had a round, flat, elongated morphology, a sharp edge texture, and an irregular position. Meanwhile, the EDX signified that the recognized chemical elements did not damage the environment, and the powder diameter ranges from 0.5-8.5 μm. The powder size complied with the fine particle powder category. To analyze the color from the dye powder application, there were color changes during each dyeing process. During all stages, from making the powder to applying the powder to the fabric, environmentally friendly technology was utilized. Therefore, this research can promote new opportunities for innovation and development of highly competitive products towards a more environmentally friendly and sustainable textile industry.

Keywords: anthocyanin; powder characteristics; mechanical thermal; natural coloring

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INTRODUCTION

The Mandalika Lombok Special Economic Zone (SEZ) is the West Nusa Tenggara (NTB) prime tourist destination with international class. Around this area, many local weaving industries are typical of the Lombok, including Sade and Rarang villages, Central Lombok. Currently, the industry is challenged to reduce negative environmental impacts. Fabric dyeing, one of the main stages in textile production, has long been a concern due to synthetic dyes that pollute water and soil. Apart from that, the use of synthetic dyes can also have an indirect impact on human health, and they contain heavy metal elements such as tin (Sn), zinc (Zn), lead (Pb), and copper (Cu) (Purwanto et al., 2012). However, synthetic dyes have several advantages, including being easy to produce, cheap, having color intensity, color variations, and better stability than natural dyes (Suarsa, Suarya et al., n.d.). As awareness of environmental issues increases, many efforts are being made to find environmentally friendly alternatives to fabric dyeing.

Teak leaves (Tectona Grandis) have emerged as a promising natural resource for fabric dye and have been widely used by the community (Ariviani, 2010). Apart from its abundant availability, teak leaves also have properties that can produce natural dyes because the young leaves contain anthocyanin compounds (Hermawati et al., 2015). Applying anthocyanin compounds as a color pigment produces a brownish-red base color (Rahayu et al., 2023). This dye belongs to the flavonoid group and has low color stability due to the influence of pH, light, and temperature (Purnomo et al., 2014). Anthocyanin is a polar dye that dissolves well in polar solvents. Young teak leaves are modified into a fine particle powder size to make it easier for the anthocyanin to dissolve, making it easy to apply as a natural dye. Using teak leaves to fabricate fine particle powder as a fabric dye is a promising innovation and a crucial step towards providing an environmentally friendly and sustainable solution in the textile industry, inspiring a commitment to sustainable practices.

Fine particle powder extracted from teak leaves offers an environmentally safe dyeing alternative and can increase the added value of textile products. The extraction method is environmentally friendly, simple, and has many fabrication results. Fine particle powder from teak leaf extract can be applied to cotton yarn and yarn. The dye solution's pH difference provides different yarn tensile strength characteristics (Kurniawidi et al., 2023). Apart from that, the dyeing process, with the addition of sizing techniques, can increase the tensile strength of cotton thread (Mardialina et al., 2018). This is confirmed by other research that reviews that the dyeing process with teak leaves, Ketapang leaves, and Banten leather can also increase the tensile strength of cotton thread (Rahayu et al., 2021). The delicate particle fabrication process of teak leaf powder can be optimized to obtain particles of the right size to penetrate well into the fabric fibers and produce long-lasting and aesthetic colors. Therefore, the characteristics of teak leaf dye powder are essential to analyze.

Based on the explanation above, much research has yet to be related to analyzing powder from teak leaves as a fabric dye. Until now, existing research has only focused on aesthetics and the resulting colors. Therefore, this research was carried out to identify the extracted powder and analyze the color changes during the coloring process. By focusing on the fabrication of fine powder particles, this research is expected to positively contribute to global efforts to reduce the environmental impact of textile production processes. Moreover, using natural dyes from teak leaves can provide significant economic incentives for local farmers and producers, fostering sustainable economic development at the regional level. By combining traditional wisdom and modern technology, this research can open the door to a more environmentally friendly and sustainable textile industry, creating new opportunities for innovation and developing highly competitive products.

METHODS

Materials

We've employed several essential tools and materials in this pilot project, including an oven, Fourier Transform Infrared (FTIR), and Scanning Electron Microscopy-Energy Dispersive X-ray (SEM-EDX). Our main ingredients for exploration are young teak leaves, alum (Al2(SO4)3), and Aquades.

Extraction Method

Creating dye powder from teak leaves is meticulous and involves the mechanical thermal method. This method progresses through 3 stages: preparation, heating, and dimension reduction. The teak leaf powder was prepared by washing and cutting the leaves to a width of 0.5 cm. They were then subjected to a heat treatment at 70 oC for two hours. The dried leaves were then carefully reduced in dimension to become fine particle powder through mechanical steps. The powdered leaves were homogenized using a 100-mesh sieve, ensuring a consistent, high-quality product.

Natural dye powder was produced by applying the dye to the fabric. The fabric was cut to 10 x 10 cm, then natural teak leaf dye powder was applied. The application of dye powder went through three primary stages: mordant, coloring, and fixation. In the mordant stage, the cloth was soaked for 12 hours in one liter of alum solution. On the one hand, an alum solution was obtained by dissolving eight grams of alum in one liter of distilled water. After the soaking process, the fabric was dried, and then the fabric was dyed. The coloring process utilized heating techniques to produce optimal color. Firstly, the dye powder was dissolved in 100 mL of distilled water with a ratio of 1: 100 (% V/V). The dye solution was heated to half the initial volume. Then, the cloth was soaked in the solution for 10 minutes and heated. The final fixation process used 10% alum solution for 30 minutes.

The extracted teak leaf powder and dyed fabric were identified for their physical and chemical properties. Some of the properties reviewed from coloring powders are alkaloids, flavonoids, tannins, water, functional groups, chemical elements, particle size, and powder morphology. Apart from that, color characteristics were also identified using the Android-based Color Analyzer and Color Grab applications. The fabric's RGB and L* a* b* values will be displayed in both applications. Next, the color tool application plots the L* a* b* values.

Analysis and Interpretation

The fine particle powder of natural teak leaf coloring is thoroughly analyzed and interpreted using several tools as needed. Phytochemical analysis produces qualitative and quantitative data on the presence of several essential dye compounds. The appearance of flavonoid compounds denoted that the material contained anthocyanins, which made a red color. It was crucial to analyze the presence of tannin compounds to demonstrate their ability to be applied as fabric dyes. The water content was investigated and elucidated based on the SNI 01-3709-1995 standard; the maximum water content in spice powder is 12%. The high or low water content indicates the shelf life of the dye powder. Furthermore, functional group analysis was carried out to strengthen the presence of coloring compounds. The hydroxyl group (O-H) is an autochrome group that functions as a binder between the dye and the fiber. Meanwhile, the double absorption group (C=C) is a characteristic of flavonoid compounds. Another study was the size and morphology of powder. This was carried out using image-J and OriginPro 8 software. The powder's morphology and size affect the powder's quality to produce color.

The chemical elements contained in the extracted powder will be identified using EDX. The identified chemical elements will categorize dyes as damaging and not damaging to the environment.

RESULTS AND DISCUSSION

Dye powder from teak leaves had been successfully produced using the mechanical thermal method. The powder extracted from teak leaves was characterized by its physical and chemical properties. Several characteristics identified were water content, phytochemicals, functional groups, chemical elements, morphology, particle size distribution, and characteristics of the color applied to the fabric. The initial stage determined the teak leaf powder's water, alkaloid, flavonoid, and tannin content (Table 1).

Table 1. Characteristics of Extracted Teak Leaf Powder

Parameter	Content (%)
Water Content	7.21
Alkaloids	1.92
Flavonoids	1.86
Tannin	7.88

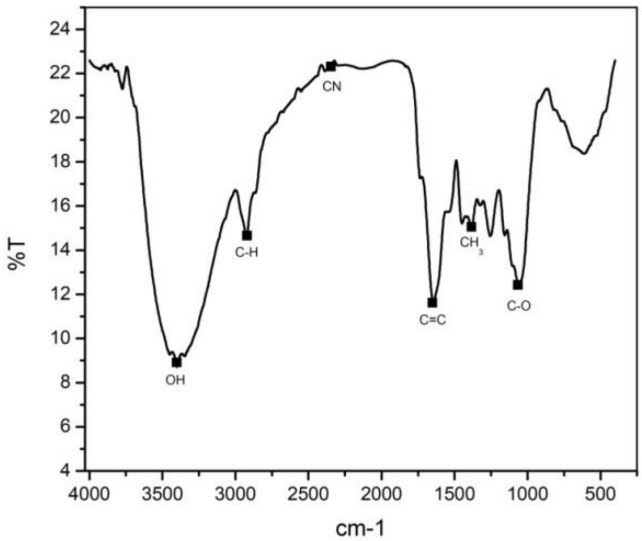


Figure 1. Analysis of functional groups of teak leaf powder using FTIR

According to the SNI 01-3709-1995 standard, the maximum water content in spice powder is 12%, so the natural coloring powder from teak leaves meets this standard. A low percentage of water content would affect the shelf life of the powder because it avoided damaging microbes that could develop at a water content of 10-15% (Winarno, 2004). Therefore, the higher the water content, the shorter the material's shelf life was. Moreover, the characteristic color produced by teak leaves was due to the presence of flavonoid compounds, which indicated that teak leaves contained anthocyanins that produced a red color. Usually, these color characteristics would appear in the typical wavelength range of anthocyanins, namely in 400-800 nm (Suzery et al., 2010). The content of this compound was confirmed through functional group analysis using FTIR (Figure 1). Tannin was a color-bearing compound in plants, especially the leaves (Febriani et al., 2021). Plants with solid tannin content may produce color on fabric and thread, while those that do not contain tannin will not have color when applied to fabric and thread.

The results of the functional group analysis of teak leaf powder were identified by matching with the reference spectrum. This shows that there are anthocyanin color pigment groups (Table 2).

Table 2. Wave Number Analysis of Anthocyanin Pigment Functional Groups

Functional groups	Wave Number (cm^{-1})	
	Literature*	Research on teak leaf powder
O-H	3424-3397	3402,91
C-H	2953-2929	2920,60
C=C	1629	1650,88
CH_3	1380	1384,51
C-O	1047	1066,56
C-N	2363	2345,93

*(Mohammed et al., 2019)

The FTIR spectrum graph divulged hydroxyl groups (O-H), a crucial autochrome group that acted as a binder between the dye and the fiber. This unique property allowed teak leaf powder to bond effortlessly with cotton fibers, making it a natural dye. Additionally, a distinct double absorption (C=C) was observed, a characteristic feature of flavonoid compounds like anthocyanin, further highlighting the exceptional nature of teak leaf powder as a dye.

With its natural elements, such as flavonoids, alkaloids, and tannin compounds, teak leaf powder is a sustainable choice for dyeing. These compounds, formed by the essential elements carbon and oxygen in teak leaves, contributed to the unique color of the powder (Armanzah & Hendrawati, 2016). Teak leaf powder is environmentally friendly, containing the highest carbon and oxygen mass percentage, as shown in Table 3.

Table 3. Data on the chemical element content of teak leaf powder using EDX analysis

Chemical Elements	% Mass
Carbon (C)	41,25
Oxygen (O)	45,82
Magnesium (Mg)	0,67
Calcium (Ca)	0,97
Potassium (K)	1,48
Silicon (Si)	5,67
Copper (Cu)	4,14

With its unique elemental composition, teak leaf powder presents a promising opportunity for use as a natural dye in eco-friendly textile production. This potential was discovered through an elemental analysis, which revealed that the chemical elements in teak leaf powder are benign to the environment, making it a viable alternative to synthetic textile dyes.

The effectiveness of teak leaf powder as a dye was further supported by its unique morphology, as revealed in our investigation. The powder's SEM 2000× magnification displayed a consistent morphology, characterized by round, flat, elongated, sharp-edge textures in irregular positions (Figure 2). This unique structure enhanced the powder's ability to be absorbed into fabric pores, ensuring the color remained steadfast and did not easily wash out.

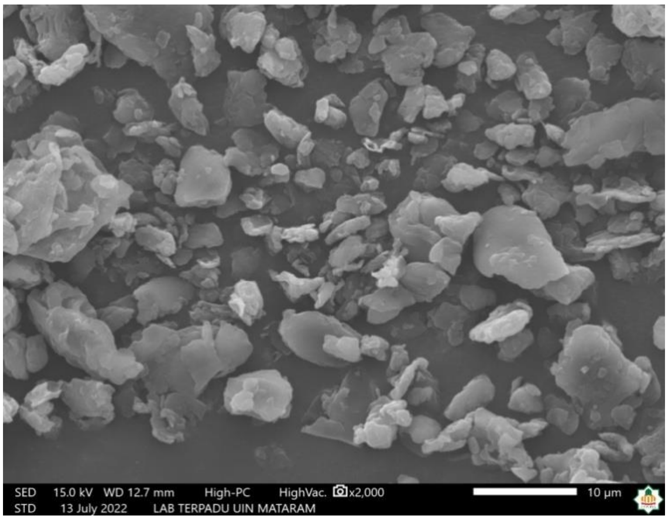


Figure 2. Morphological analysis of teak leaf powder using SEM.

The unique and significant morphology of teak leaf powder, characterized by its homogeneous size, was crucial. The powder diameter distribution disclosed a maximum length of 10 μm (figure 3), further highlighting its distinct properties.

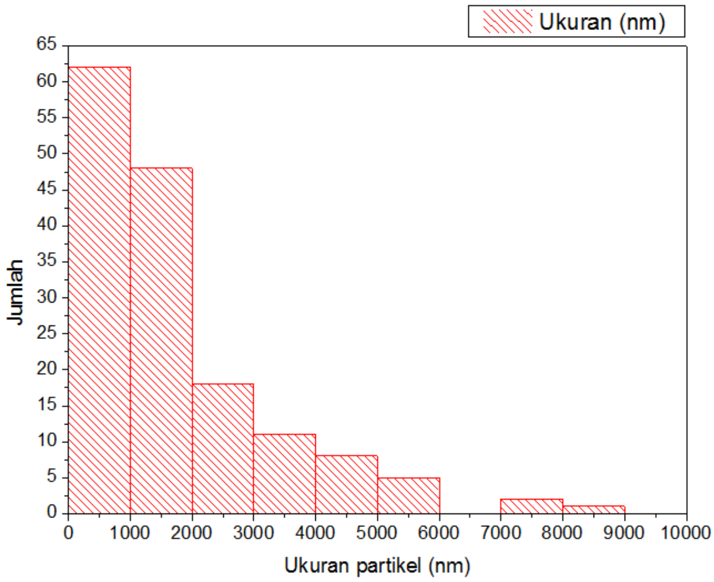
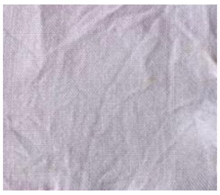


Figure 3. Analysis of particle size distribution of teak leaf powder

The histogram revealed an average distribution of powder diameter sizes ranging from 0.5 μm to 8.5 μm. This small size is crucial as it enhances the powder's ability to dissolve in water, making it easier to disperse. Given these unique properties, teak leaf powder showed promise as a natural dye. The powder was applied to the fabric to demonstrate this, and the discovering color characteristics were identified (Table 4).

Table 4. Analysis of color characteristics using red, green, and blue analysis techniques.

Fabric Treatment	Picture	R	G	B	Color Code
No treatment		209	201	214	#D1C9D6
Mordant		130	141	164	#828DA4
Coloring		142	112	109	#8E625F
Fixation		107	56	67	#6B3843

The fabric dyeing technique used three basic processes, namely mordanting, dyeing, and fixation, showing different color textures on the fabric. The differences in color between the various processes analyzed were apparent in Table 4. The mordanting process helped to open pores and expand the yarn fibers to absorb dyes more easily (Lestari et al., 2018). Therefore, the acidic process did not provide a significant color change from the base color of the fabric. Meanwhile, in the coloring process, color changes occurred due to the content of natural dyes in the form of anthocyanins, tannins, and alkaloids. The fixation process could lock the color in the fabric, but this process gave an insignificant color change from the dyeing process. Usually, using alum does not alter the direction of the color produced; it only faded the color slightly (Afan et al., 2020).

CONCLUSION

Delicate particle powder extraction has been successfully extracted from teak leaves. The extracted powder has also been successfully applied as a fabric dye. Specifically, the teak leaf powder obtained had a water content of 7.21% and contained alkaloids, flavonoids, and tannins. The presence of anthocyanin compounds is strengthened by the appearance of a typical double group (C=C), a flavonoid. Besides that, the extracted powder has a round, flat, elongated morphology, sharp edge texture, and irregular position, and the powder diameter ranges between 0.5-8.5 μm. Furthermore, the dye powder application findings show color changes in each dyeing process. Through this research, it is vital to develop optimal dyeing techniques to obtain colors that do not fade quickly on fabric.

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Declarations

Author Contribution	:	Arif Budianto: Conceptualization, Writing - Review & Editing ; Diah L. Dewi : Analisis Data ; Susi Rahayu : Writing - Original Draft, Validation and Supervision ; Alfina T. Alaydrus : Editing and Visualization; Dian W. Kurniawidi : Formal analysis, and Methodology ; Halil Akhyar : Coloring Analize and Translation.
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