Coconut (*Cocos nucifera* Linn.) Root Extraction and Application as A Fabric Dye with Different Particle Sizes and Extraction Methods

R Pujiarti¹ and O A Putri¹

¹Department of Forest Products Technology, Faculty of Forestry, Universitas Gadjah Mada. Jl. Agro No. 01. Bulaksumur Yogyakarta, Indonesia

Email: rpujiarti@ugm.ac.id

Abstract. Coconut (*Cocos nucifera* Linn.) root can be used as an alternative to natural dyes because it contains color pigments in the form of flavonoids. Extraction of natural dyes is affected by several factors such as the type of solvent, extraction temperature, ratio of solvent and raw material, particle size, stirring, and extraction time. This study ware aims to determine combination factor of the particles size and extraction methods of coconut root dye on the characteristics and colour fastness of the fabric products. The coconut root powder in 60 and 40 mesh sizes were extracted by boiling distilled water and maceration with 70 and 95% ethanol, respectively. The coconut root dye was tested for the color characteristics and the dye solution was applied to the fabric and tested for the color fastness. The results showed that the particle size and extraction methods used had a significant effect on color intensity while pH value and color index were not significantly different. The highest color intensity was 2.044, the effect of temperature at 30 was 1.949, and the effect of temperature at 100°C was 1.920. The pH value of the coconut root dye solution is acidic with an average pH of 5.85 while the color names from the test results using NADIM 2021 produce three color categories, namely foxtrot, tobacco brown, and pale gold. Although it is not significantly affected by the combination of material size factors and the extraction methods of coconut root dye solution, the results of the color fastness test tend to meet the standards of SNI 8302-2016 regarding the quality requirements for the fastness of written batik. The average grey scale value for each test is 3-4 (Good enough), the staining scale value is 4-5 (Good), and the sunlight resistance test value is 4 (Good).

1. Introduction

Dyes in textiles can be categorized into two types, namely natural dyes and synthetic dyes [9]. The need for synthetic dyes for production purposes in the textile industry, according to the Statistics Indonesia in 2021, has been in increasing trend every year. Approximately 11668.20 tons of tanning extracts, tannins, dyes, paints, putties, varnishes, including synthetic dyes were produced to meet export needs that year [3].

The use of synthetic dyes tends to produce high concentration of liquid waste [6], because in textile dyeing process, only 5% of dyes will be bound to the fabric, while the remaining 95% will be washed out with liquid waste [5]. Synthetic dyes that are disposed of with waste generally contain azo compounds and their derivatives. Azo compounds left for a long in the environment will cause negative impacts, both for the health and the environment.
Negative impacts caused by excessive use of synthetic dyes has brought some of public awareness to return to using natural dyes. One alternative for natural dye that can be used is coconut root. Coconut root extract contains flavonoids, anthocyanins, and tannins, which are color-generating pigments [2].

Coconut root extraction is affected by several factors, including solvent type, extraction temperature, solvent ratio and raw material, particle size, stirring, as well as extraction duration [15]. Size of material will affect the efficiency of extraction method being used [13]. The use of smaller material and high temperature extraction method will increase contact between solvent and extracted material. The smaller particle size of material can produce stronger color. Another study stated that in addition to particle size, differences in extraction methods can also affect the results of the dye extract. The dye obtained by the boiling extraction method gave optimal results on the intensity and fastness of the fabric compared to the maceration extraction method [4]. In addition, the type of solvent used in the selected extraction method also affects the results of dye extraction. Extraction of mangrove bark with 95% ethanol solvent produced a higher dissolved tannin content than the extraction with 70% ethanol solvent and water [16]. Ethanol is a solvent that is more effective in attracting anthocyanin compounds in the extraction of young teak leaves compared to distilled water [8]. Ethanol is the best extraction solvent for almost all low molecular weight compounds such as saponins and flavonoids [18].

Research related to natural dyes from coconut roots as fabric dyes is still limited. Based on the explanation above, the study was conducted on the effect of material sizes and extraction methods of coconut root dye as an alternative to natural fabric dyes. The resulting dyes were tested for color characteristics including color intensity, temperature effects of 30°C and 100°C, and the name of the color and fastness of the dyed fabric (washing fastness 40°C, acid sweat fastness, and sunlight fastness).

2. Materials and Method

2.1. Materials

This study was used coconut root particle size of 40 - 60 mesh and particle size of 20 - 40 mesh, distilled water, 95% ethanol, 70% ethanol, primissima mori fabric, batik wax, alum, soda ash, and ferro sulfate.

2.2. Extraction

Fresh coconut roots were obtained from Tepansari Village, Loano District, Purworejo Regency, Central Java Province, Indonesia. The coconut roots are then air-dried before were grinding and sieved in order to obtain coconut root particles escaped 40 mesh retained 60 mesh and particle escaped 20 mesh retained 40 mesh. Each size of particle weighing 100 grams then extracted by boiling method using distilled water at 100°C for one hour and maceration method using 95% and 70% ethanol for 24 hours, respectively. The extraction liquid then separated by simplicia before being used directly in fabric dying.

2.3. Characteristic Tests of Dye Extract

2.3.1. Color Intensity. Color intensity test was carried out by diluting each 2 ml of coconut root extract in a ratio of 1:4. Dilution of the extract color intensity was then measured using a spectrometer UV WPA S800 at a wavelength of 325-365 nm. the test results for each sample are obtained from the highest color intensity value.

2.3.2. Effect of Temperatures at 30°C and 100°C. Effect of temperature on color intensity was carried out to determine changes in color intensity values at temperatures of 30°C and 100°C. Color intensity test was preceded by dilution of the extract in a ratio of 1:4. The diluted extract was then heated at temperature 30°C and 100°C for 1 hour. After heating, the color intensity was measured using spectrometer UV WPA S800 at a wavelength of 325-365 nm.

2.3.3. Acidity (pH). The pH value of the dye solution was obtained by measuring the acidity of the solution using pH meter.
2.3.4. **Color Index**. Color index test was carried out on the fabric that had been dyed in coconut root dye solution (*Cocos nucifera* Linn.) by 10 times. Resulting color on the fabric was compared with NADIN 2021 (Natural Dye Indexation) to determine the color index of the dyed fabric.

2.4. **Color Fastness Tests**
2.4.1. **Fabric Treatment**. The fabric used in this research was primissima mori cotton fabric. Before dying process, the fabric was treated with tawas and soda ash to increase the fabric absorption on dyes (mordanting process), then the fabric was depicted of batik motifs using canting (traditional tools to make batik). The fabric then was dyed in coconut root dye for 30 minutes and was repeated 10 times. The dyed fabric than has been to wax removing (pelorodan) process. After that, it was post mordanted using Ferro sulfate solution to fix the dye on the fabric. Then fabric was dried without being exposed to direct sunlight to avoid the fabric color fading.

2.4.2. **Washing Fastness at 40°C**. Washing fastness 40 °C was carried out by placing the fabric in a vessel containing steel marbles and soap solution. Vessel was heated at 40°C before being placed in limitest machine. Sample was washed at 40°C and then dried. The dried fabric was acidified in 0.014% acetic acid solution for one minute at 27°C before being dried again by ironing the fabric at a temperature of 135°C – 150°C. Washing fastness value of 40°C was obtained by comparing the result of the colored fabric with staining scale and grey scale standard fastness.

2.4.3. **Acid Sweat Fastness**. Fastness to acid sweat test was done by soaking the fabric in an artificial acid sweat solution for 15 – 30 minutes. Soaked and dried fabric was placed between 2 glass plates and weighed with a pressure of 10 pounds (60 g/cm²). Fabric was then put in a perspiration tester and in an oven at 38±1°C for 6 hours. Fabric was compared with the standard staining scale and grey scale.

2.4.4. **Sunlight Fastness**. Sunlight fastness of fabric was tested by installing a sample fabric on the window glass and letting the fabric be under direct sunlight during 9 am – 3 pm (Jakarta time). The color change of fabric was compared with the standard grey scale.

![Flow Chart of Method](image_url)

**Figure 1.** Flow Chart of Method
3. Results and Discussion

3.1. Color Characteristic

3.1.1. Color Intensity. Color intensity of coconut extract vary depending on the particle size of samples and extraction methods that has been used. The highest color intensity value from this study was found in the sample with particle size of 40 - 60 mesh in boiling extraction method using distilled water, which was 1.944 (Table 1). The result show that the differences of particle size and extraction method that been used was affected the results of the color intensity value.

| Extraction method | Particle Size | Mean  |
|-------------------|---------------|-------|
|                   | U1            | U2    |       |
| E1                | 2,044         | 1,888 | 1,966 |
| E2                | 1,768         | 1,372 | 1,570 |
| E3                | 1,386         | 0,802 | 1,094 |
| Mean              | 1,733         | 1,354 | 1,543 |

Note:
U1 : 40-60 mesh particles
U2 : 20-40 mesh particles
E1 : Extraction by boiling distilled water
E2 : Extraction by maceration method with 95% ethanol
E3 : Extraction by maceration method with 70% ethanol

Color intensity of coconut root dye extraction by boiling method using distilled water solvent produces the highest intensity color absorbance compared to the maceration extraction method using 95% ethanol or 70% ethanol solvent. This shows that high temperature that been used in the extraction process can speed up the mass transfer from the solute to the solvent, because temperature affects the transfer coefficient value of a component (Mardiah, 2010). In addition to the extraction method, size of material also affects the density and intensity of the resulting color. The smaller particle size the greater contact area between particles and solvent which makes solvent easily extract the compounds contained in particles [1]. Therefore, a high color intensity value was obtained in a combination of particle size of 40 - 60 mesh and boiling extraction method using distilled water.

3.1.2. Effect of Temperatures at 30℃ and 100℃. This test to determine the change in color intensity of coconut root dye when heated at temperature of 30℃ and 100℃. Results show that color intensity value of coconut root extraction that has been heated at temperature of 30℃ tends to be lower than color intensity at initial temperature. In addition, heating at temperature of 100℃ also tends to produce a lower color intensity value than the extraction heated at a temperature of 30℃ (Fig.1). Therefore, it can be said that higher heating temperature, the lower color intensity value.

Based on these results, it can be seen that heating coconut root solution at a temperature of 100℃ for 1 hour will affects the anthocyanin pigment in the root dye so that it reduces the concentration and absorbance value of the dye solution. This is in accordance with the statement of Sutrisno (1987) in Wijaya et al. (2001) that an increase in temperature can cause decomposition and changes in the structure of the pigment, which results in bleaching of the dye solution. In addition, high temperatures can also reduce the color of the dye due to the decomposition of anthocyanin pigments from the aglycone form to calcon [17].
Figure 2. Effect of Temperature of 30°C and 100°C on Color Absorbance of Coconut (Cocos nucifera Linn.) Root Dye
Note: U1E1 (particle size 40 - 60 mesh + boiling extraction method with distilled water), U1E2 (particle size 40 - 60 mesh + maceration extraction method with 95% ethanol), U1E3 (particle size 40 - 60 mesh + maceration extraction method with 70% ethanol), U2E1 (particle size 20 - 40 mesh + boiling extraction method with distilled water), U2E2 (particle size 20 - 40 mesh + maceration extraction method with 95% ethanol), U2E3 (particle size 20 - 40 mesh + maceration extraction method with 70% ethanol).

Effect of heating the coconut root dye solution at temperatures of 30°C and 100°C showed the highest absorbance value in the combination of particles obtained from the sieve with particle size of 40 to 60 mesh and the boiling extraction method with distilled water, which was 1.949 and 1.920 (Figure 1). The high absorbance value cannot be separated from the use of smaller material sizes and high temperature extraction method. Amount contact between solution and material will result in the amount of dye dissolved, so that dye solution becomes more concentrated.

Results of absorbance value tests on the solution with effect of heating at temperatures of 30°C and 100°C indicates that higher temperature used produce lower absorbance value of the solution. This is in accordance with the statement of Wijaya et al. (2001) that high temperatures can reduce color stability of dye solution due to the decomposition of anthocyanin pigments from aglycone to chalcone, resulting in bleaching of the solution [17]. However, an increase in temperature below 50°C not affected the occurrence of pigment changes because that range of temperature is still classified as the optimal temperature where the sample can still maintain the stability of color pigment.

3.1.3. Acidity (pH). Acidity/pH of coconut root (Cocos nucifera Linn.) dye solution was measured using a pH meter, and resulted in an average total pH of 5.85 (Table 2). The test results show that each sample has an acidic pH with a pH value below 7, due to the pH value of the solvent used. The pH value between solvent and the coconut dye extract tended to remain unchanged, therefore it can be said that the difference in the particle size and the extraction method did not affect the pH value.

| Extraction Method | Particle Size | Mean |
|-------------------|---------------|------|
|                   | U1            | U2   |      |
| E1                | 6,24          | 6,13 | 6,19 |
| E2                | 5,65          | 5,73 | 5,69 |
| E3                | 5,71          | 5,62 | 5,66 |
| Mean              | 5,87          | 5,83 | 5,85 |

Note: see Table 1.
The lower pH of solvent used, produce better quality of coconut root dye extract. This is probably because anthocyanin pigments contained in coconut root extract more stable in acidic solutions than neutral or alkaline solutions [7]. Lower pH of solution, can more reddish and stable dye extract because the anthocyanin pigment at an acidic pH will be in the form of red flavium cations [10]. In addition, lower pH of the dye extract, produce better fabric color fastness [17].

3.1.4. **Color Index**. Combinations of material size and extraction method on coconut root dye solution (Cocos nucifera Linn.) obtained three color categories, namely Foxtrot, Pale Gold, and Tobacco Brown (Table 3). The colors obtained, based on the chi-square test, is not directly affected by differences in the size of the material and the extraction method used. However, the combination of the particles obtained from sieve with escaped size of 40 mesh and retained size of 60 mesh and the boiling extraction method with distilled water tends to produce a darker color. This is probably due to this combination is able to dissolve more dyes in coconut roots (Cocos nucifera Linn.), which is indicated by the high absorbance value of the solution in the color intensity test, and this has led the color of the dyed fabric becomes darker (Hidayati and Marfu'ah, 2010).

| Particle Size | Extraction Method | Repetition | Color Indexation |
|---------------|-------------------|------------|-----------------|
| U1            | E1                | RGB, CMYK, Hex | Pantone Number Pantone Name |
| E2            | U1                | RGB, CMYK, Hex | Pantone Number Pantone Name |
| E3            | E1                | RGB, CMYK, Hex | Pantone Number Pantone Name |
| E2            | U2                | RGB, CMYK, Hex | Pantone Number Pantone Name |
| E3            | E1                | RGB, CMYK, Hex | Pantone Number Pantone Name |

Note: see Table 1.

3.2. **Fabric Color Fastness**

Color fastness of fabric which dyes with coconut (Cocos nucifera Linn.) root dye showed in Table 4.
Table 4. Fabric Color from Coconut (Cocos nucifera Linn.) Root Dye

| Combination of Factor | Fastness to Washing at 40℃ | Fastness to Acid Sweat | Fastness to Sunlight |
|-----------------------|-----------------------------|------------------------|----------------------|
|                       | Staining Scale | Gray Scale | Staining Scale | Gray Scale          |                        |
| U1E1                  | 4-5           | 3-4        | 4-5           | 3-4                 | 4                      |
| U1E2                  | 4-5           | 3-4        | 4-5           | 3-4                 | 4                      |
| U1E3                  | 4-5           | 4          | 4-5           | 3-4                 | 4                      |
| U2E1                  | 4-5           | 3-4        | 4-5           | 3-4                 | 4                      |
| U2E2                  | 4-5           | 4          | 4-5           | 4                   | 4                      |
| U2E3                  | 4-5           | 4          | 4-5           | 4                   | 4                      |

Note: see Figure 1.

Fastness Categories: 5 (very good), 4-5 (good), 3-4 (fairly good), 2-3 (enough), and 1 (bad)

Color fastness test showed that staining scale and sunlight fastness value of batik fabric that has been dyed in coconut root dye was on the same category, which was at a good category. Meanwhile the grey value was around good and fairly good category (Table 4). It was showed that difference between particle size and extraction method that been used was just affected the grey scale value of fabric. High value of grey scale indicates that color fabric will not fade easily.

Color fastness test showed that combination of particle size and extraction method factors with best fastness was found in the particle size of 20 - 40 mesh and maceration extraction method using 70% ethanol solvent. This is probably influenced by values of pH, where the lower pH, produce better fastness of fabric. Lower pH value gave more stable dye and applied fabric with dye tend to have good fastness [17]. In addition, results of particle size and extraction method factor that was used in this study have mostly met the standards of SNI 8302-2016 regarding the quality requirements of written batik, so it can be declared suitable for use as a dye for batik

4. Conclusion

Combinations of material size and extraction method of coconut (Cocos nucifera Linn.) root solution only affects color intensity value, temperatures at 30℃ and 100℃, but they has no effect on the acidity value (pH), color name, and fabric color fastness (washing fastness at 40℃, acid sweat fastness, and sunlight fastness). Best combination was obtained in the size factor of escaped size of 40 mesh and retained size of 60 mesh and boiling extraction method with distilled water solvent because it produces more concentrated color solution and darker-colored fabric which suitable as batik dye.

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