Preliminary study of cassava leaf extract feasibility as a natural textile dye

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Abstract. One of the requirements of the batik textile industry is to use natural, safe, and environmentally friendly dyes. We researched different particle sizes and extraction temperatures to achieve the optimal chlorophyll concentration and mordant concentration for color durability and effectiveness. Before extraction, cassava leaves were dried and crushed to various sizes, i.e. 20, 40, and 60 mesh. Extraction temperatures were set to 30, 40, 50, 60, and 70 °C. Mordant concentrations were varied to 20, 30, and 40 gram/l, and were assessed as pre-mordanting, meta-mordanting, and post-mordanting. The chlorophyll concentration was measured using a UV-Vis spectrophotometer at a 465 nm and 665 nm wavelength. It was found that cassava leaves had the potential to become a natural dye for textiles because of their high chlorophyll concentration. The highest concentration was 16.001 mg/l, obtained from a simplicial size of 40 mesh and extraction temperature of 30 °C while the optimal result at a concentration of mordant 40 grams by using a meta-mordanting process.

1 Introduction

Natural dyes, for various things including textiles, have attracted attention due to their safety and environmental friendliness. The use of artificial dyes that contain azo groups is prohibited and is tied to environmental requirements [1]. Synthetic dyes such as nylon, wool, silk, leather, and cotton are extensively used in textile industries. They are preferred because of their low prices, repeatability, and wide range of bright shades with considerably improved colorfastness properties. However, some synthetic dyes have been evaluated as highly cytotoxic and carcinogenic to mammalian cells and act as liver tumor promoters. They can also decrease food intake capacity, growth, and fertility rates, cause damage to the liver, spleen, kidney, and heart, and inflict lesions on skin, eyes, lungs, and bones [2].

Natural dyes have seen a resurgence in popularity recently due to their minimal allergic reaction, biodegradability, renewability, and environmental friendliness [3]. Plants, minerals, and animals can all be directly or indirectly used as natural coloring agents. It can be extracted using a conventional method or boiled. Plant elements such as bark, stem, leaves, roots, flowers, seeds, and sap can be utilized to make natural dyes [4].

It has been investigated and demonstrated that cassava leaves contain the highest concentration of chlorophyll among all sources of the green pigment [5]. Chlorophyll, in general, consists of two different structures, i.e. chlorophyll A and chlorophyll A. The main difference lies in the carbon-7 position, i.e. chlorophyll A has a methyl (–CH3) group while chlorophyll B has an aldehyde (–CHO) group [6]. This difference results in color changes, with chlorophyll A showing blue-green and chlorophyll b showing blue-yellow. Both structures are shown in Figure 1.

Chlorophyll is found in chloroplasts, an organelle that is an intercellular lamella. Proteins in the form of a protein-chlorophyll complex shield it from harm. Chlorophyll is stable in the complex because of the protein-lipid bilayer that envelopes it [7].

The absorption maxima of chlorophyll A are about 430 nm and 662 nm, while chlorophyll B is about 453 nm and 642 nm [8]. Since cassava leaf extract pigments are mainly composed of a mixture of chlorophylls, it has absorption peaks at wavelengths of 410 and 665 nm. The observed absorption peak agrees with the absorption data of chlorophyll pigment [9].

Fig. 1. Chlorophyll A and B structures [8].

The extraction process often requires heat until a specific temperature. However, natural pigments—particularly chlorophyll—are heat susceptible materials [10]. A conventional procedure is used to extract the chlorophyll from dried leaves using water as the solvent. The simplicia was finely pulverized into powder as the particle size greatly affected the maximization of the extraction yield [11].

Normally, natural dyes have a low adherence for fibers, so it is important to use mordants to fix the color.
Mordants are substances that can bond chemically with natural colorants and adhere to the fiber. They are usually metal alum salts, tin chloride, copper sulfate, or iron sulfate [12].

Mordanting can be classified into three types, the re-mordanting process is formed by first applying the mordant and then dyeing, the meta-mordanting process is formed by simultaneous application of the dye and mordant, post-mordanting is formed after treatment of the dyed material with the mordant [13].

In this research, we used aluminum sulfate as a mordant. Considering the effect of temperature and in chlorophyll extraction, it is necessary to study the optimum condition to find the optimum process conditions to obtain the highest concentration of chlorophyll.

2 Research Methodology

This research used a Completely Randomized Design method arranged in a factorial manner with the variation of particle size 20, 40, and 60 mesh and extraction temperature 30, 40, 50, 60, 70 °C. The mordant concentrations were varied by 20, 30, and 40 gram/L while the mordanting process was assessed as pre-mordanting, meta-mordanting, and post-mordanting.

2.1 Procedures

2.1.1 Determining the maximum chlorophyll concentration.

Cassava leaves were collected from a local farm in Sukoharjo, Indonesia. They were cut and dried at 40 °C. The dried leaves were crushed and sieved into several sizes, i.e. 20, 40, and 60 mesh. Next, they were dissolved in distilled water at a ratio of 1:4 and the mixtures were heated for 15 minutes at different temperatures of 30, 40, 50, 60, and 70 °C.

The mixtures were filtered and 1.5 ml of each filtrate was taken, mixed with 8.5 mL of 99.5% acetone, and refrigerated for 12 hours. The obtained supernatant is measured for absorbance at wavelengths of 645 and 663 nm using a UV-Vis spectrophotometer. The chlorophyll concentration was determined by the equation (1):

\[
\text{Chlorophyll concentration} = 20.2A_{645.00} + 8.02A_{663.0}
\]  

The highest chlorophyll concentration will be used in the dyeing process.

To determine the effect of particle size and temperature on chlorophyll extraction, this research was designed to use two factors completely randomized design, as shown in Table 1.

3 Results and Discussion

3.1 Optimal chlorophyll concentration

From the extraction experiments with variations in particle size at different temperatures, chlorophyll concentrations obtained were shown in Table 3.

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Chlorophyll Concentration (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>8.375, 16.001, 10.622</td>
</tr>
<tr>
<td>40</td>
<td>8.977, 13.059, 7.541</td>
</tr>
<tr>
<td>50</td>
<td>8.289, 11.056, 3.227</td>
</tr>
<tr>
<td>60</td>
<td>8.290, 10.809, 3.721</td>
</tr>
<tr>
<td>70</td>
<td>8.170, 10.756, 3.046</td>
</tr>
</tbody>
</table>

The absorbance was determined by measuring the natural dye solution. The effects of particle size and extraction temperature and their interaction with absorbance numbers are determined by two-way ANOVA.
As temperature increases, chlorophyll concentration decreases. Chlorophyll is susceptible to heat at temperatures above 30°C [13]. Chlorophyll was found in the plant matrices where it bound to protein molecules. If the proteins that shield chlorophyll are denatured by heat, or boiling, it will leave chlorophyll in its free form which is unstable and susceptible to heat.

Particle size also affected the extraction. The smaller the particle, the greater the contact surface area. This will boost the extraction to process better. It was proven that particle sizes 40 mesh produced more chlorophyll compared to 40 mesh. However, in smaller sizes, particles tended to cluster and block the solvent so extraction did not take place well [14].

3.2. Effect on Mordanting

Tables 4, 5, and 6 show the percentage of dye as chlorophyll concentration after it was used to color the fabric after each immersion.

Table 4. The concentration of chlorophyll on the remaining dye solution with 20 grams of mordant

<table>
<thead>
<tr>
<th>Immersion</th>
<th>Mordanting process</th>
<th>Pre-, mg/l</th>
<th>Meta-, mg/l</th>
<th>Post-, mg/l</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>21.85622</td>
<td>4.79384</td>
<td>8.89762</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>25.16538</td>
<td>5.9871</td>
<td>8.59492</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>57.54732</td>
<td>4.72106</td>
<td>6.30138</td>
<td></td>
</tr>
</tbody>
</table>

For 20 grams of mordant, pre-mordanting showed the highest concentration of chlorophyll which meant that the dyeing process was not optimal. In the third immersion, the concentration increased significantly, presumably due to the re-dissolving of the dye into the water.

Table 5. The concentration of chlorophyll on the remaining dye solution with 30 grams of mordant

<table>
<thead>
<tr>
<th>Immersion</th>
<th>Mordanting process</th>
<th>Pre-, mg/l</th>
<th>Meta-, mg/l</th>
<th>Post-, mg/l</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8.55542</td>
<td>5.76164</td>
<td>8.87742</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>7.90636</td>
<td>5.07604</td>
<td>9.06308</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>9.26864</td>
<td>5.1004</td>
<td>12.83624</td>
<td></td>
</tr>
</tbody>
</table>

An increase amount of mordant resulted in lower concentration of chlorophyll in the remaining solution. However, Table 4 shows that there is still a non-uniform pattern of increase and decrease in chlorophyll concentration. This shows that the amount of mordant used was not enough.

Table 6. The concentration of chlorophyll on the remaining dye solution with 30 grams of mordant

<table>
<thead>
<tr>
<th>Immersion</th>
<th>Mordanting process</th>
<th>Pre-, mg/l</th>
<th>Meta-, mg/l</th>
<th>Post-, mg/l</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15.48866</td>
<td>4.4959</td>
<td>7.32176</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>9.90552</td>
<td>4.74186</td>
<td>7.16046</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>8.93832</td>
<td>4.03606</td>
<td>7.85764</td>
<td></td>
</tr>
</tbody>
</table>

Mordanting with 40 grams of mordant showed the chlorophyll concentration became more uniform. In this case, meta-mordanting resulted in the lowest chlorophyll concentration. Therefore it was concluded that meta-mordanting provided the best results.

The result of the dyeing process on cotton textile with a particle size of 40 mesh, extraction temperature of 30°C, and meta-mordanting process gave a yellow color as shown in Figure 2.

Fig. 2. Result of cotton textile after dyeing process

4 Conclusion

This study explored the possibility of cassava leaves as an eco-friendly textile dye. Based on research findings, it was found that the ideal temperature for chlorophyll extraction was 30°C since this temperature prevented the chlorophyll structure from degradation. For the coloring process, the meta-mordanting procedure with a particle size of 40 mesh produced the best and most vivid yellow colour on cotton fabric.

References

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