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APPLICATION OF NATURAL DYE FROM *Musa paradisiaca Var. Balbisiana Colla* LEAF STALK ON COTTON FABRIC WITH VARIATION OF FIXATION

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ABSTRACT

The purposes of this study are to apply the natural dye obtained from *Musa paradisiaca Var. Balbisiana Colla* leaf stalk on cotton fabric with variation of fixation. The experiment was carried out by several steps including extraction of natural dye, mordanting process, dyeing process, fixation process and testing the application of natural dye on cotton fabric. The application testing was evaluated based on the color fastness againts washing and rubbing, color changes with gray scale and color staining with stainning scale. The results of this study show that extract of natural dye from *Musa paradisiaca Var*. *Balbisiana Colla* leaf stalk is applicable as natural dye in textile. Moreover, using fixation can increase the color fastness in which alum 10 g/L provided the best color fastness, ie scale 3-4 (good enough) for color fastness againts washing and dry rubbing, and 4 (good) for wet rubbing.

Keywords*: Natural dye, Musa paradisiaca leaf stalk, fixation, cotton fabric.*

INTRODUCTION

Synthetic dyes are dyes made by reacting chemicals. Synthetic dyes have advantages over natural dyes, namely they have stronger coloring power, are more uniform, more stable and cheaper [1]. However, the use of synthetic dyes is less environmentally friendly. The liquid waste generated from this industry can contain heavy metals whose type depends on the dye used. Even very small amounts of dye in water (10-50 mg/L) can easily be seen and affect the appearance, clarity of water and dissolved gases in water bodies [2].

Natural dyes are dyes that can made from plants, animals, minerals or Micro-organisms. However, most natural dyes come from plants. Almost all parts of the plant when extracted can produce dyes, such as plant skins, fruit and leaves [3]. Natural dyes have the advantage of being non-toxic, renewable and environmentally friendly [4]. This has moved the world of modern science and technology to revive the use of natural dyes, increase production, cost effectiveness and consistency of color [5]. However, natural dyes have disadvantages including low fastness when washed. What can be done to overcome this problem is to add a fixation so that the color fastness can be increased. The fixation process is an important step because in this process the color pigments that have not been bound can be bound[6].

Bananas are plants from the Musaceae family, living in different types of tropical areas. Almost all parts of Indonesia can be planted with bananas [3]. Based on data from the National Statistics Agency, banana production in Indonesia in 2017 reached 7,162,680 tons and in 2018 it increased to 7,264,383. Banana plants are plants that only bear fruit once and then die. So that after harvesting the banana tree will only become waste because it has not been widely used [7], one of which is the banana midrib. The unique thing about bananas is the sap which is very difficult to clean when it sticks to cloth or clothes. Banana sap contains tannin compounds which give it its brown color, in which varies from 3.7 to 5.5% [8], with tannin content in banana midrib is higher about 7.68% [2]. Furthermore, other studies suggested that extract of banana leaf stalk of Musa paradisiaca Balbisiana Colla showed a higher absorbance value of tannin content identified using spectrophotometer than *Musa paradisiaca*, Linn *(pisang raja)* only about 0.67% and *Musa acuminata Cavendish* (*pisang ambon),* 0.33% [9,10,11]. In addition, natural tannin can be extracted from wood, bark, fruit, leaves, roots and plant galls [12].

There are three steps of treatment in applying natural dye on fabric, namely preparation, mordant and fastness [13-19]. Mordant is chemicals that bond with dye through fixation process has three types, namely metal salts or metallic, tannin and oil-mordant [12,15]. Some studies were conducted for application of natural dyes using different kind of mordants [13,14,16,18]. The environmentally friendly fixing agents commonly used are alum ($Al_2(SO_4)_3$), ferrous sulfate ($FeSO_4$), and calcium oxide or lime (CaO). Different types of fixators will produce different colors, where there is a difference in color intensity [20]. The right concentration will affect the color intensity and fastness of the fabric [21].

From fixation process, the fabric then analyzed for washing fastness, light fastness, and rub fastness according to the international standard, namely ISO 105-C03 or ISO 105-C06, ISO 105-B02, and ISO 105-X12 [13-14,16]. The wash fastness and rub fastness of fabric coloration using 1% $SnCl_2$ and 10% resulted rating good with number 4-5 from scale 1 (poor) – 5 (excellent) [13]. Other studied also showed good rating by using acid dye, natural dye added with 2% alum pre-mordant and natural dye with 10% alum post-mordant [14]. In addition, using tannic acid, metallic acid and mixture of tannic acid with metallic acid toward wash fastness showes good rating (3-4) and excellent rating (4-5) for rubbing fastness [17]. However, there some studies that suggested to improve the combination of natural dyes and mordant since the wash fastness rating were poor [19]. Moreover, according to our knowledge not many studies were conducted on utilizing the tannin compound extracted from banana as natural dye on fabric.

Therefore, in this study, we explore the application of tannin compound obtained from banana as natural dye on cotton with variation of common eco-friendly mordant. In addition, the fixation result is tested for fastness according national standard (SNI).

METHODS

1. Tools and Materials

The tools used include a hot plate, thermometer, analytical balance, gray scale, staining scale, laundrymeter, and crockmeter. The material used is the *kepok* banana leaf stalk, water, calcium oxide (CaO), alum ($Al_2(SO_4)_3$), ferrous sulfate ($FeSO_4$), soda ash (Na_2CO_3), teepol, aquades.

2. Extraction of tannin compound from Musa paradisiaca balbisiana colla.

Weigh the ingredients that have been dried and cut into small pieces as much as 3 kg. Then boil with water solvent with a ratio of ingredients and solvent of 1:10 for 2 hours at a temperature of 70°-80°C. Then filter the resulting extract.

3. Mordanting Process

Soak nine pieces of cotton fabric with a size of 30x40 cm in a teepol solution of 2 mL/L for 2 hours, after that let the fabric air dry. Then, prepare a mordant solution containing 8 g/L alum ($Al_2SO_4)_3$ and 2 g/L soda ash (Na_2CO_3). Mordan solution is boiled until it boils, then put the fabric and boil it for 1 hour. Then turn off the heater, and let the cloth soak for 1 night. Remove the fabric from the soak and rinse it. Let the fabric air dry.

4. Fabric Coloring Process

Mixing 5 g/L alum ($Al_2(SO_4)_3$) into the *kepok* banana extract. Then put the fabric in the solution and boil it for 30 minutes at a temperature of 70°-80°C. Next, remove the fabric and let it air dry. Repeat the boiling steps 6 times.

5. Fixation Process

Make a fixation solution, namely a solution of alum with a concentration of 5 g/L, 10 g/L, and 15 g/L. Leave the solution for 12 hours and take out the clear solution. Next, put the fabric that has been colored in each fixation solution for 5 minutes. Remove the fabric and let it air dry. Then the fabric is boiled with 2ml/L teepol solution at 70°C for 15 minutes and rinsed with water until clean. Then let the fabric air dry. Carrying out the fixation process for the ferrous sulfate and calcium oxide.

6. Color Fastness Testing

The tests carried out on the fabric are the color fastness against washing (SNI. 080285-98) and the color fastness test against rubbing (SNI. 080288-89).

RESULTS AND DISCUSSION

The extract of *kepok* banana leaf stalk contains tannin which is indicated by a positive result when 1% $FeCl_3$ solution is added, which produces a green-black color, according to the reaction in Figure 1 [22].

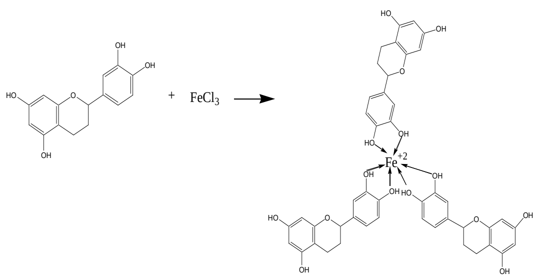

Figure 1. Reaction of tannin and $FeCl_3$

In this study, the fixation process was carried out by varying the type and concentration of the fixation substance. The types of fixing agent used are $Al_2(SO_4)_3$, CaO, and $FeSO_4$ solutions, while the variations in the concentration used are 5 g/L, 10 g/L, and 15 g/L.

The results of dyeing can be seen in Table 1. The dyeing with the alum fixing agent produces a reddish cream color, the using ferrous sulfate produces an orange-brownies color, and the dyeing with the calcium oxide fixing agent produces a light cream color.

Table 1. Fabric Dyeing Results

Type of Fixation	**Concentration (g / L)**		
	5	10	15
Alum			
Ferrous sulfate			
Calcium oxide			

Color Fastness

In this study, the quality of the dyeing on the fabric was determined through a color fastness test against washing and rubbing. The assessment is carried out by comparing the color change with a color change standard. Known standards are the standards issued by the International Standards Organization (ISO) in the form of a gray scale for assessing the color change of a test sample and a staining scale for assessing color staining on white cloth. The results of the color fastness test against washing based on the gray scale (GS) can be seen in Figure 2, while the staining scale (SS) value can be seen in Figure 3.

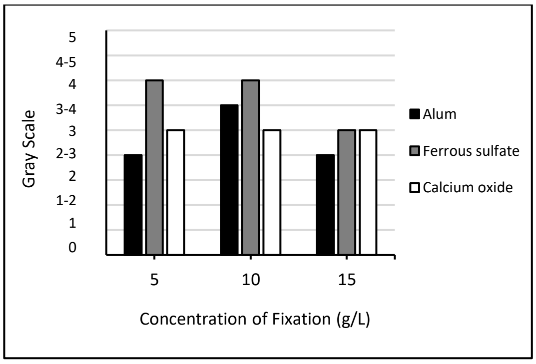

Figure 2. Gray Scale Value on Color Fastness Against Washing

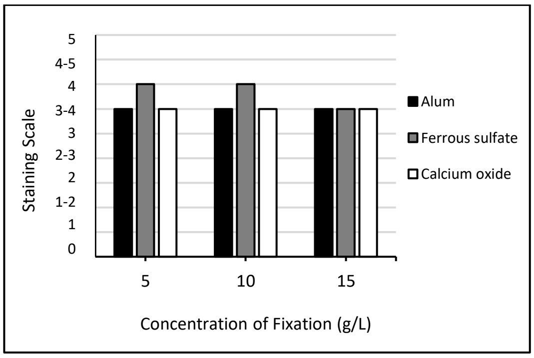

Figure 3. Staining Scale Value on the Color Fastness Against Washing

The variation of alum 5 g/L, 10 g/L, and 15 g/L as mordant with tannin natural dye give GS and SS values, respectively: 2-3 (less) and 3-4 (good enough); 3-4 (good enough) and 3-4 (good enough); 2-3 (less) and 3-4 (good enough). In the same manner with addition of tannin natural dye with ferrous sulfate fixing agent 5 g/L, 10 g/L, and 15 g/L give GS and SS values, respectively: 4 (good) and 4 (good); 4 (good) and 4 (good); 3

(enough) and 3-4 (good enough). Meanwhile, the use of calcium oxide 5 g/L, 10 g/L, and 15 g/L give GS and SS values respectively: 3 (enough) and 3-4 (good enough); 3 (enough) and 3-4 (good enough); 3 (enough) and 3 (enough) with tannin as natural dye.

According to the minimum standards for fabrics, it is declared that to be acceptable for consumers, the scale rating of gray scale (GS and stain scale (SS) must meet 3-4 (good enough). Thus, the fabrics which can be acceptable for consumers are the one using alum 10 g/L, ferrous sulfate 5 g/L and 10 g/L as mordant.

Aside gray scale (GS) and staining scale (SS), the fabric was also tested for color fastness against dry rubbing and wet rubbing. The results can be seen in Figures 4 and 5.

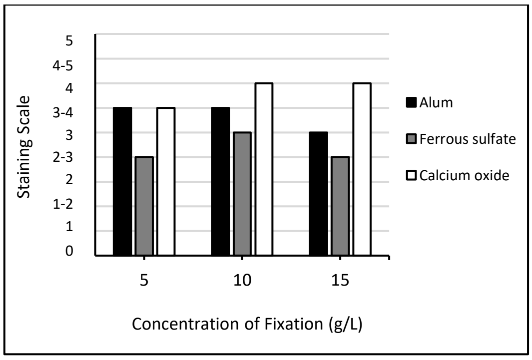

Figure 4. Staining Scale Value on the Color Fastness Against Dry Rubbing.

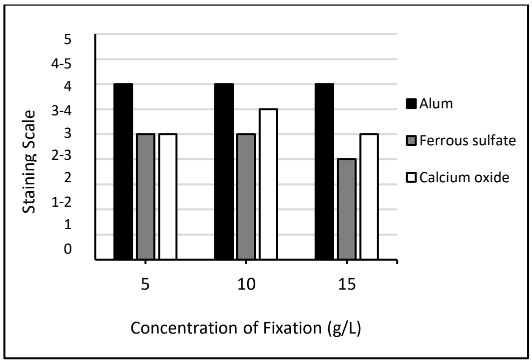

Figure 5. Staining Scale Value on Color Fastness Against Wet Rubbing.

In the alum fixation agent 5 g/L, 10 g/L, and 15 g/L give color fastness values to dry rubbing and wet respectively: 3-4 (good enough) and 4 (good); 3-4 (good enough) and 4 (good); 3 (enough) and 4 (good). Then, the ferrous sulfate fixing agent 5 g/L, 10 g/L, and 15 g/L give color fastness values to dry and wet rubbing, respectively: 2-3 (less) and 3 (enough); 3 (enough) and 3 (enough); 2-3 (less) and 2-3 (less). Meanwhile, the use of calcium oxide 5 g/L, 10 g/L, and 15 g/L give color fastness values to dry and wet rubbing, respectively: 3-4 (good enough) and 3 (enough); 4 (good) and 3-4 (good enough); 4 (good) and 2-3 (less).

The minimum standard for the fabric to be declared worthy of acceptance by consumers is when it gives a value of 3-4 (good enough). So, the fabrics which can acceptable for consumers are using alum 5 g/L and 10 g/L, calcium oxide 10 g/L.

Based on Figure 2-5, it can be seen that the fixing agent can increase the color fastness of the fabric. This is because the fixing agent forms a complex with dye and fiber. Likewise, the right concentration of fixing agent affects the color intensity and fastness of fabrics treated with natural dyes [21].

Furthermore, dyeing with 10 g/L alum showed the best color fastness compared to other results where the fastness test for washing and dry rubbing showed a value of 3-4 (good enough) and the test for wet rubbing showed a value of 4 (good). Whereas at a concentration of 15 g/L there was a decrease in color fastness. This can occur because at this concentration the color pigment is decomposed due to the pH of the solution that is too acidic or alkaline. Differences in ionic properties, pH of each fixing agent affect the evenness and strength of the bonds between fibers and color pigments [23].

It is worth to notice that this result is positively comparable with other studies that used different natural dye with metallic mordant [13], synthetic dye with eco-friendly mordant [14], and mixture of tannic acid and metallic acid [17]. In addition, this result exceed the result of same studied carried out utilizing combination of natural dye and metallic mordant [19].

The color fastness with alum as fixing agent can be caused by the strong bonds in the tannin-alum complex. The stability of complex compounds is influenced by several things, including the influence of the central metal ion and the influence of ligands [24]. The ligands contained in this study are the same, namely tannins, so the stability of the complex compounds is only affected by the central metal ion. A stable complex com-posed of a central ion with a small radius and a large charge. Therefore, the smaller the metal ion, the greater the ionic potential, and the more stable the complex.

The central ion in the tannin-alum complex is Al^{3+}, in the tannin-ferrous sulfate complex is Fe^{2+}, and in the tannin-calcium oxide complex is Ca^{2+}. Based on the calculations of Table 2, it can be seen that the ionic potential of Al^{3+} is greatest compared to Fe^{2+} and Ca^{2+}. This causes the bond strength of the tannin-alum complex to be stronger and the resulting complex compounds to be more stable. The more stable the complex, the more difficult it is to decompose, so the better its fastness.

Table 2. Calculation of the Central Atomic Potential

	$Al_2(SO_4)_3$	$FeSO_4$	CaO
Central atom	Al^{3+}	Fe^{2+}	Ca^{2+}
The charge of the central atom	+3	+2	+2
The ionic radius of the central atom (Å)	0.50	0.76	0.99
$\frac{\text{Charge}}{\text{Radius}}$	6	2.63	2.02

The mechanism for the formation of complexes from cellulose fibers and dyes with metal fixing agents can be illustrated in Figure 6. The bond that occurs between the metal fixing agent and cellulose fibers is a coordination bond [24].

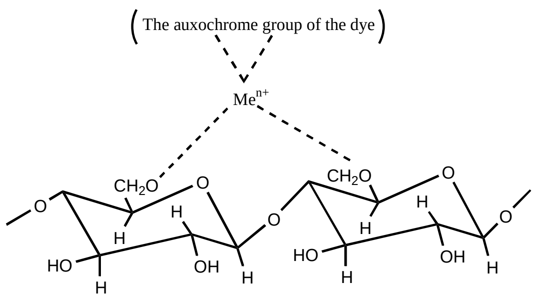

Figure 6. The Bonding Mechanism of Cellulose Fibers and Dyes with Metal Fixing Agent [12,15].

CONCLUSION

Based on the results of the study, it can be concluded that the extract of tannin compound from banana leaf stalk can be used as a natural dye. Color fastness can be improved by adding a fixation. The best color fastness is showed by the variation of the alum fixation agent 10 g/L, which shows a value of 3-4 (good enough) in the test against washing and dry rubbing, and a value of 4 (good) in the test against wet rubbing. The results of color fastness is in accordance with standard international.

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