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Coloring of Mahogany (Swietenia Macrophylla King.) on Textiles with Mordant Process and Fixation Against Fastness

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ABSTRACT

This study aimed to assess the color fastness of mahogany dye on various fabrics (cotton, rayon, silk) in response to sunlight exposure, soap washing, and staining subsequent to mordanting and fixation with alum and lime solutions. The research followed a systematic approach comprising material sorting, drying, pulverization, and powder creation and sifting. Sawdust from mahogany was subjected to Soxhlet extraction with ethanol as the medium at a temperature of 78.4℃ for a duration of 4 hours. This process yielded a filtrate, which was subsequently concentrated via distillation. Prior to the dyeing process, each fabric was mordanted using a solution of alum and lime. The dyeing process was repeated five times, after which the fabric was air-dried. The fixation process involved the immersion of cotton, rayon, and silk fabrics in various concentrations of alum and lime (40g/l, 50g/l, 60g/l, and 70g/l), followed by aeration. The UV Vis spectrometry absorbance test revealed an absorbance of 0.545A for the distilled mahogany dyes, with a yield of 7.653%. Results indicated a noteworthy sunlight fastness rating of 4.8, achieved with a lime fixative solution at concentrations of 40g/l for cotton and 70g/l for silk. Soap washing resistance was found to be optimal (4.8) on silk fabric treated with lime solution at concentrations of 50g/l and 60g/l. Stain resistance was observed to be highest on rayon fabric (4.7) across all concentrations of lime solution (40g/l, 50g/l, 60g/l, and 70g/l). Mahogany dyeing with an alum solution fixative tended to yield a brown color on cotton and rayon, while silk fabric displayed an orange hue. On silk fabrics, the application of a lime fixative solution resulted in a dark brown color at a lime concentration of 70g/l. This study provides insights into the color fastness of mahogany dye on different fabrics and the influence of various mordanting and fixation solutions, contributing to the broader understanding of natural dye application in textile.

1. INTRODUCTION

Traditionally, textile dyes have been categorized into two types: natural and synthetic. The employment of natural dyes, derived from various parts of plants, can be traced back to early textile manufacture when fibers were colored for weaving into fabric and clothing [1-3]. Despite their long-standing use, the advent of synthetic dyes, due to their ease of use, vibrant results, and practicality, led to a decline in the use of natural dyes [4].

However, a recent resurgence in the demand for natural dyes has been observed, attributed to their exotic tones and environmental friendliness [5, 6]. Natural dyes are derived from a range of plant parts: roots, tubers, wood, stems, bark, sap, fruit stalks, leaves, flowers, fruit, and fruit skin. A myriad of plants, including tall plants, jambal, legeran, teak, mahogany, soga, indigo, and purple sweet potatoes, are known to contribute to the natural color palette. Notably, mahogany, which can yield a brown hue, is a particularly underexplored source of natural dye [7-11].

Mahogany, particularly its waste (shavings), has been suggested as a promising alternative for batik dye due to its ability to produce a suitable brown color. The pigment is believed to be derived from flavonoids, a yellow-brown compound present in mahogany [12]. Additionally, mahogany bark extract has been found to contain tannin and alkaloid compounds, which are also potential sources of dyes [12].

Extraction of the dye is performed using the Soxhlet method, with ethanol as the solvent at a temperature of 78.4℃ for 4 hours [13-15]. According to Ramadhania [16], the extraction process at this temperature yielded a color intensity of 0.011 A, compared to 0.0079 A at 30℃. Moreover, the color change in the fastness to sunlight on primisimamori fabric was moderate, ranging from 3.5 - 4.5 [16].

Before the dye can be applied to textiles, a mordanting process with alum solution is undertaken to ensure maximum dye absorption [17-19]. Mordanting agents, or metallic salts, are known to enhance the properties of natural dyes on fibers and fabrics [20-22].

The present study, therefore, aims to explore the natural color of mahogany in terms of intensity/absorbance, yield, and fastness to sunlight, soap washing, and staining on white cotton cloth for variations in the concentration of the fixative solution.

The fixative solutions investigated in this study include alum ($Al_2(SO_4)_3$) and quicklime ($CaCO_3$), with various concentrations used in the dyeing of cotton, rayon, and silk fabrics. This study aims to contribute to the understanding of mahogany as a source of natural dye, and its potential application in the textile industry.

2. MATERIALS AND METHOD

The type of mahogany shavings used is an exotic type from Magetan, East Java, Indonesia. The material used is mahogany wood shavings (Swietenia macrophylla King.) as natural color material, fixation material in the form of alum, quicklime. Other materials used, technical 96% ethanol as the extraction medium, distilled water as a diluent for the spectrophotometric feed solution. For application, cotton, rayon and silk are used.

The main equipment used include: the soxchlet extraction Unit has a flask with a capacity of 500ml, made of glass pyrex, distillation Unit, 500ml volume flask capacity made of pyrex glass equipped with a pyrex condenser, analytical balance: Kern ABT analytical balances, model 220-4M, weighing capacity 220 g, material stainless steel weighing plate , heater: Thermo scientific cimaree Hotplate stirrer, maximum temperature 540℃, stirrer: magnetic ceramic material, 60mesh sieve, UV-1800 Shimadzu spectrophotometer, measuring cup, beaker glass, Gray schale, Staining schale.

The mahogany shavings were sorted from non-mahogany shavings and other impurities, ground into powder, then sieved through a 60 mesh sieve.

2.1 Extraction and distillation of dyes

Weighed 25 grams of mahogany powder, wrapped using filter paper, then put into the soxchlet column. Put 500ml of 96% ethanol solvent (technical) into a boiling flask. Boiling flasks were assembled using a soxchlet apparatus at a temperature of 78.4℃ for 4 hours. The result of the extraction is a filtrate (a mixture of dyes and solvents). The obtained filtrate was thickened by distillation process at a temperature of 78.4℃ for 2-3 hours, obtained a thick solution of brownish mahogany dye.

2.2 Mahogany dyestuff analysis

a. Analysis of the yield of mahogany dye by weighing the solution before and after the distillation process;

b. Analysis of color intensity/absorbance, by preparing a specimen solution for UV Vis spectrophotometry feed with a wavelength of 570 nm;

c. Making specimens by diluting thick mahogany dye obtained from distillation, weighing 0.5 grams dissolved in distilled water to a volume of 100 ml.

2.3 Application of mahogany dye on fabric

a. Preparation of textile applications, cutting of cotton, rayon and silk fabrics, drawing of fabrics, waxing with canting;

b. The mordant process, which is dissolving 10 grams of alum with water up to a volume of 1 liter, put the cloth and then heated at 50℃ for 30 minutes and removed and let stand for 24 hours, then the cloth is washed and aerated;

c. The dyeing of the fabric in a solution of mahogany color (the concentration of mahogany dye is 20g/l) is carried out at a temperature of 40-50℃, with 5 times dyeings and each time the dye is aerated on each fabric;

d. The fixation process, also called the locking process, is the process of soaking the fabric after dyeing with alum and lime solvents. The fixation process by preparing cotton, rayon and silk fabrics, the solvents for fixation were alum and lime with concentrations of 40g/l, 50g/l, 60g/l and 70g/l for 30 minutes at each cloth, followed by sag process and drying;

e. All specimens before the dyeing process were in the form of cotton, rayon and silk which had a white color.

2.4 Color fastness analysis

a. Fastness test to soap washing

Testing steps: Prepared the test material in the form of colored cloth measuring 10 × 4 cm, then placed between the two pieces of white cloth and then sewn on the four sides. The test sample was stirred for 30 minutes in a 5g/l soap solution at a temperature of 40℃-50℃. Stirring is done by hand, then the test sample is pressed against the beaker wall every two minutes without being removed from the solution.

The sample of the test material was rinsed twice with cold distilled water and then rinsed with cold running water for 10 minutes. Squeezed test sample, the seam removed on all three sides so that the test sample only has one seam (one side only). Then assessed with gray scale for color changes from the sample the test material.

b. Color fastness test to sunlight

Testing Steps: Cut a colored cloth measuring 10 × 20 cm or 5 × 10 cm, then the cloth is placed on a board with the condition of the cloth being partially exposed to sunlight and partly covered with cardboard. Next is testing the color fastness to sunlight This is done by exposure to sunlight for 6 hours at the time of effective sunlight, namely 09.00-15.00.

Testing steps: Cut a colored cloth measuring 10 × 20 cm or 5 × 10 cm, then placed on a board with the condition of the cloth being partially exposed to sunlight and partly covered with cardboard. Furthermore, the color fastness test to sunlight was carried out by exposure to sunlight for 6 hours at the time of effective sunlight, at 09.00-15.00. Meanwhile, the color fastness test against soap washing was carried out using a soap solution reagent containing 5 g/l distilled water, by measuring the color change using the gray schale standard. The gray scale standard was used to assess color changes in the color fastness test. The gray schale value determines the level of color contrast from the lowest level to the highest level, which is 1:1-0 to 5:5-4.

c. Color staining test on white fabrics: The schale staining standard was used to assess color staining on white fabrics to test color fastness, carried out by comparing stained and unstained white fabrics against the differences described by schale staining and expressed by adam chromaticity. schale from the lowest level to the highest level of 1 (poor) to 5 (very good).

2.5 Data analysis

Data obtained from the processing of laboratory experiments. Data analysis used bivariant ANOVA (Analysis of Variance) at a significance level of $\alpha = 5\%$ compared to P. The results of P with $\alpha = 0.05$ if there was a significant difference then continued with the Tukey test at a significant level of α = 5%. The data consists of influence variables, namely the type of fixation solvent (alum and lime). Response variables are fastness to sunlight, soap washing, staining of white cotton cloth.

3. RESULTS AND DISCUSSION

The yield of mahogany dye after the distillation process is 7.563%. The greater the yield of the dye, the more concentrated the dye obtained, this is due to the large difference between the weights before and after the distillation process. Color is a collection of light that can be measured intensity/ absorbance and wavelength. Measuring the absorbance intensity of the dye using a UV Vis spectrophotometer. When there is a white light is passed through a solution of dye (colored) then the wavelength of radiation will be absorbed selectively.

The result of absorbance/intensity of mahogany dye is 0.545A tested at a wavelength of 570nm. The portion of the light absorbed depends on the number of molecules that interact with the light. If the dye produced is a concentrated solution, the intensity/absorbance obtained is high, this is due to the large number of molecules that interact with light. The results of the color intensity test from the mahogany shavings waste dye solution, the absorbance value is relatively high, meaning that the dye solution from mahogany wood shavings waste is quite concentrated. This is in accordance with the research of Ramadhania et al. [16], the absorbance value of mahogany color intensity tested at a wavelength of 600nm resulted in an average of 0.0035A. This method uses extraction by immersing cold, hot water at 30°C, and boiling at 100°C and no thickening process is carried out (Figure 1).

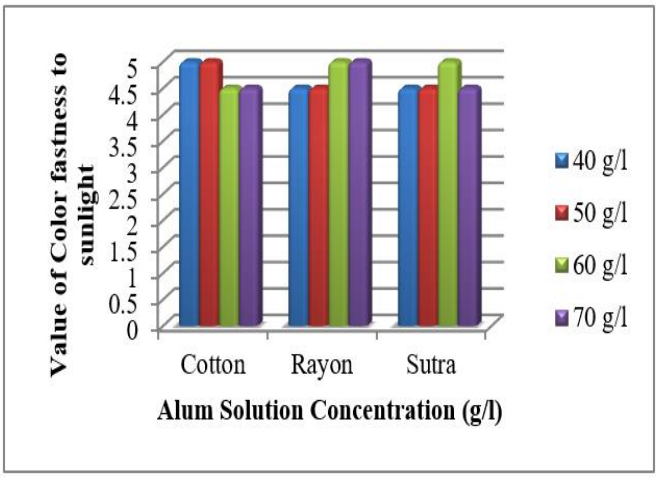

Figure 1. Color fastness to sunlight with variations in the concentration of alum solution (g/l) on cotton, rayon, silk fabrics

Table 1. Results of analysis of color fastness to sunlight, soap washing, staining on white cotton fabrics, for colored cotton, rayon, silk fabrics mahogany wood with varying concentrations of alum fixation solution

Fabric Type, Alum Fixation Concentration (%)	Test to	Color Resistance Test Value Against Sunlight (Gray Scale)		Color Fastness Test Value Against Soap Washing and Staining Test on White Cotton Fabric			
				Fastness Value (Gray Schale)		Desecration Value (Staining Schale)	
		Repetition	Average	Repetition	Average	Repetition	Average
Cotton without fixation	1	5	5	4-5	4-5	4-5	4-5
	2	5		4-5		4-5	
Cotton, 40% alum	1	5	5	4-5	4-5	4-5	4-5
	2	5		4-5		4-5	
Cotton, 50% alum	1	5	5	4-5	4-5	4-5	4-5
	2	5		4-5		4-5	
Cotton, 60% alum	1	4-5	4-5	4-5	4-5	4-5	4-5
	2	4-5		4-5		4-5	
Cotton, 70% alum	1	4-5	4-5	4-5	4	4-5	4-5
	2	4-5		4		4-5	
Rayon without fixation	1	4-5	4-5	4	4	4-5	4-5
	2	4-5		4		4-5	
Rayon, 40% alum	1	5	4-5	4	4	4-5	4-5
	2	4-5		4		4-5	
Rayon, 50% alum	1	4-5	4-5	4	4	4	4-5
	2	5		4		4-5	
Rayon, 60% alum	1	5	5	4	4	4-5	4-5
	2	5		4		4-5	
Rayon,70% alum	1	5	5	4	4	4-5	4-5
	2	5		4		4-5	
Silk without fixation	1	4-5	4-5	4	4	4-5	4-5
	2	4-5		4		4-5	
Silk, 40% alum	1	4-5	4-5	4	4	4-5	4-5
	2	5		4		4-5	
Silk, 50% alum	1	4-5	4-5	4	4	4-5	4-5
	2	4-5		4		4-5	
Silk, 60% alum	1	5	5	4	4	4-5	4-5
	2	5		4		4-5	
Silk, 70% alum	1	4-5	4-5	4	4	4-5	4-5
	2	4-5		4		4-5	

Figure 2 shows that the color fastness to sunlight when fixing a 40g/l lime solution is highest on cotton fabric, namely 4.5-5. The color fastness of the 70g/l lime fixation solution showed the highest value for silk fabric, 4.5-5. In this study, the fastness test was carried out against sunlight, using a laundry meter. The results of gray schale analysis on soap washing and staining on mahogany dyes with variations of alum and quicklime fixator solutions, respectively 40g/l, 50g/l, 60g/l and 70g/l. Tested several coloring qualities, among others, 1. color fastness to sunlight; 2. color fastness to soap washing; 3. color fastness to staining on white cotton fabrics; 4. post-fixation color results. The discussion of test results is described below and pictures of test results can be seen from Figure 1 to Figure 4. The results of the mahogany color fastness test to sunlight after the fixation process with alum solution of 40g/l, 50g/l, 60g/l and 70g/l on cotton, rayon, silk as shown in Figures 1 and 2. The results of gray scale analysis of sunlight, soap washing and staining of mahogany wood dye with various alum fixator solutions are shown in Table 1.

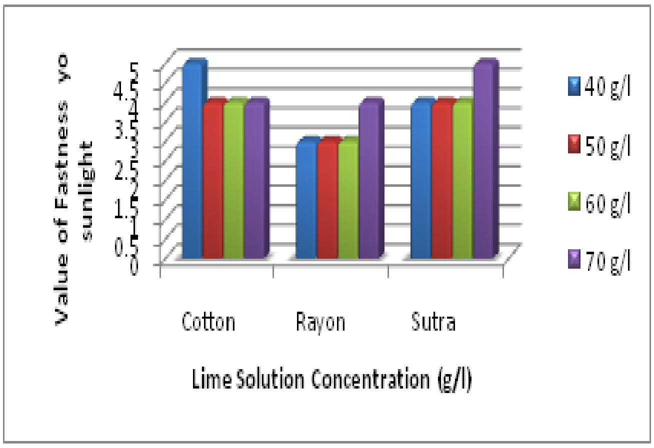

Figure 2. The value of color fastness to the sun with variations in the concentration of lime (g/l) on cotton, rayon and silk fabrics

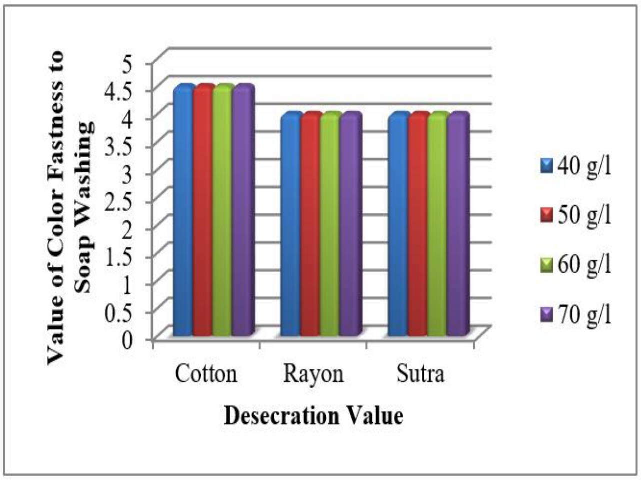

Figure 3. Color fastness to soap washing with variations in the concentration of alum solution (g/l) on cotton, rayon, silk fabrics

The results of the color fastness to sunlight on alum have a high value of 4.5-5; 4-4.5 (good to very good) on cotton fabric. The fastness value of rayon is 4-4.5(40.50g/l); 4.5-5 (60.70g/l) and silk is 4.5-5 (60g/l); others low. This is because Al^{3+} from alum and Ca^{2+} from lime are well absorbed in the fabric fibers thereby strengthening the color bond in the fabric [16], and the pores of cotton fabrics are larger than rayon and silk fabrics. In lime solution the high fastness value is only on 40g/l cotton fabric, for silk on 70g/l lime. This is because the sun contains ultraviolet light and heat energy attacks the dye molecular chain, causing the color to fade (fading) and the color-carrying group in the molecular activity is reduced. This is in accordance with the study, the fixation process was carried out with alum solution, lime with extraction with water media at a temperature of 30°C, 100°C. The results of the mahogany color fastness test against soap washing after the fixation process with alum solution of 40g/l, 50g/l, 60g/l and 70 g/l on cotton, rayon, silk as shown in Figures 3 and 4.

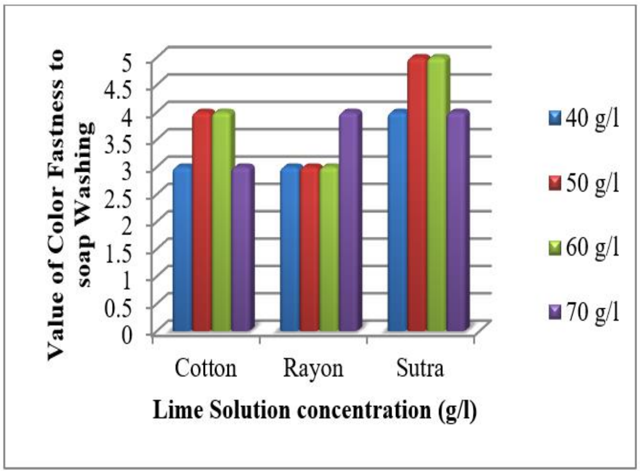

Figure 4. Value of color fastness to soap washing compared to lime concentration (g/l) on cotton, rayon and silk fabrics

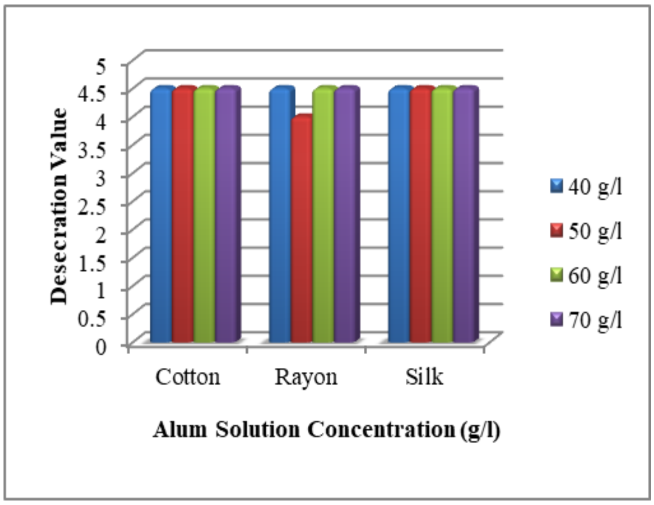

Figure 5. Color fastness to staining compared to variations in the concentration of alum solution (g/l) on cotton, rayon, silk fabrics

The value of color fastness to soap washing after fixation of lime solution on silk fabric (with 50g/l, 60g/l) was high, namely 4.8. This is because it is determined by the strength of the bond that occurs between the fiber and the fiber, the dyestuffs and fixators of alum Al^{3+} and Na^{+} as well as the fixator of lime Ca^{2+} with Na^{+} from soap will cause bonds between ions and natural dyes that have been in the solution. fiber binding to natural dye molecules becomes larger. this is in accordance with the research of Ramadhani's research [16] on primisima mori fabric. Color fastness to staining of white cotton fabrics after fixation with alum solution of 40g/l, 50g/l, 60g/l and 70g/l on cotton, rayon, silk fabrics as shown in Figures 5 and 6.

The value of color fastness after the fixation process against soap washing is quite high for cotton equal to 4.4, rayon fabric and silk the same fastness value is 3.7.

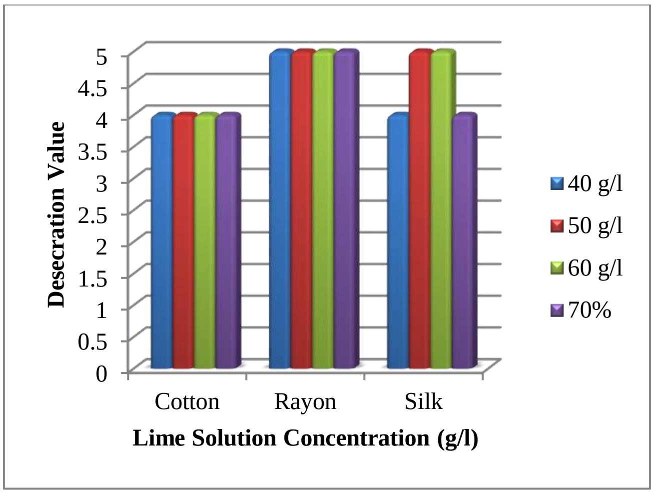

Figure 6. Stain value with variations in lime concentration (g/l) on cotton, rayon and silk fabrics

According to the staining scale test, the value of fastness to staining on the alum fixator was high on average for cotton and silk in good categories, 4-4.5; 4-4.5; 4-4.5; 4-4.5 means that there is no staining (bleeding) of white cotton fabric on rayon with a concentration of 50g/l in sufficient category. The value of fastness to staining on the fixator of lime solution on rayon, each concentration is good 4-4.5; 4-4.5; 4-4.5; 4-4.5. At 50g/l silk fabric, 60g/l staining fastness value is good. This is because the fixation solution of alum and lime can strongly bind mahogany dye to the fabric with both alum and lime. Also caused by the dye with the fabric diffusion occurs, adsorption, penetration is locked by alum and lime so that it is strongly bound [12, 20]. This was because the alum and lime fixation solution bind the mahogany dye firmly to the fabric well. In accordance [20], that if the fiber bonds with a strong color, the color will not fade.

The results of mahogany coloring on cotton, rayon, and silk fabrics were obtained by manual observation on cotton fabrics that tend to be brown, the higher the concentration of 70% alum, the browner the color. On light brown rayon and on silk it is light orange, the higher the 70g/l alum concentration, the darker it will be. In the results of dyestuffs with lime water fixation, the higher the concentration, the browner the color yields on cotton, rayon and silk fabrics. The darkest brown color in 70g/l lime water staining is silk, and rayon is lighter than cotton and silk. The higher the fixator concentration, the darker the color results [1, 13, 14, 23].

4. CONCLUSIONS

This research focuses on the fixation process using the respective concentrations of 40g/l, 50g/l, 60g/l and 70g/l alum and lime solution in the application of dyeing cotton, rayon, silk fabrics can be concluded as follows:

1. Good sun fastness 4.8 (4.5-5) on cotton fabrics with 40.50g/l alum, on rayon fabrics with 60.70g/l alum, on silk fabrics with 60g/l. In a good solution of lime 4.8 (4.5-5) 40g/l cotton fabric and 70g/l on silk fabric;
2. Good fastness to soap washing 4.3 (4-4.5) on cotton fabrics with concentration 40g/l, 50g/l, 60g/l and 70g/l alum. On silk fabrics the washing resistance of soap is 4.8 (4.5-5) with 50g/l, 60 g/l lime;
3. Staining resistance to white cotton fabrics was a good average of 4.3 (4-4.5) on cotton fabrics with all concentrations of alum solution. In lime solution the staining resistance is 4.7 (4.5-5) on rayon fabrics at all concentrations of the solution;
4. Coloring mahogany with a solution of mordant and alum fixator on cotton, rayon tends to brown, silk tends to orange. The use of lime fixator on cotton, rayon, brown silk. The color of the silk fabric is dark brown at a fixator concentration of 70 g/l lime;
5. The higher the concentration of alum and lime fixators, the darker the color of the orange, brown, and dark brown fabrics on cotton, rayon and silk.

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