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Mordanting Methods for Dyeing Cotton Fabrics with Dye from Albizia Coriaria Plant Species

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Abstract- The study investigated the effects of different methods of application of selected mordants on dyeing woven cotton with dyes from the stem bark of Albizia coriaria. The methods of application of mordants used includes; pre-mordanting, simultaneous mordanting and post-mordanting. The effects on cotton analyzed are color fastness to; light, washing, wet and dry rubbing and color characteristics on CIELab color coordinates. Aqueous extraction method was used to extract the dye. Some selected mordants were used for dyeing viz; alum, ferrous sulphate, and iron water. In the control dyeing without the use of mordants, very good fastness were registered with the following fastness ratings; for washing (4-5), dry rubbing (5), wet rubbing (5) and light (4). The natural dye is a substantive dye since it registered very good fastness grades without the use of mordants. The use of mordants improved color fastness to light from ratings of (4) to (5) and (6) for iron water and ferrous sulphate and a poor fastness of (3) was recorded for alum. Post-mordanting method registered the best overall fastness results and the best color strengths K/S values and color saturation values C. However, the most brilliant colors were registered with simultaneous mordanting method with all mordants. However, there was no observable effect of mordanting methods on the redness or yellowness of color.

Index Terms- Albizia Coriaria, color fastness, mordanting, substantive dye.

I. INTRODUCTION

Traditionally, dyes from plants were used for coloring silk, wool and cotton fibers but overtime these were replaced by cheaper synthetic dyes [1]. Dyes from natural sources like plants, fungi, insects, animals and minerals are referred to as natural dyes. The majority of natural dyes are from plant sources namely; roots, berries, barks, leaves, seeds, woods and other organic sources such as fungi and lichens[2]. With the invention of synthetic dyes in 1856, the prominence of natural dyes slacked because the synthetic dyes had some advantages over natural dyes like color fastness, good reproducibility of shades, brilliance of color and easy to use [3]. The synthetic dye stuffs are suspected to cause allergies, and are carcinogenic and detrimental to human health [4]. Natural dyes derived from plants have recently gained economic advantage over synthetic dyes because of their non-toxic and biodegradable nature [5]. Due to the current eco-consciousness, researchers' attention has been shifted to the use of natural dyes for dyeing textile materials [6].

Most natural dyes need chemical species called mordants for binding the dye to fabrics to improve color fastness. Mordants help in binding of dyes to fabric by forming a chemical bridge from dye to fiber thus improving the staining ability of a dye with increasing its fastness properties [7]. The color fastness and characteristics of natural dyes on fabrics are influenced by the mordanting method applied whose effects vary with the source of the dye.

In Uganda, great potential exists for natural dyes from dye-yielding plants. In a recent study, it has been reported that several plant species in Uganda possess dye-yielding properties [8]. *Albizia coriaria* is one of these plants with dye-yielding properties. A. coriaria is a pioneer species common in wooded grassland, woodland and thicket. Its absence in closed canopy rainforest is largely the result of its high light requirements. Its distribution range extends from West Africa through eastern, southern and parts of central Africa.

The extracts from *Albizia coriaria* plant species revealed the presence of tannin moieties in their molecular structures. Tannins have been reported to be the most important ingredients which are necessary for dyeing with natural dyes, especially to brown shades of color [9]. The extract of the plant bark reveals the presence of steroids and triterpenoids, Coumarins, tannins, reducing sugars and alkaloids. Some of these compounds are associated to dye-yielding properties in plants.

In the present study, dye extracts from the stem bark of *Albizia coriaria* were used to dye plain woven cotton fabrics by application of various selected mordants and mordanting methods. In each case color fastness to washing, rubbing, light and color characteristics were determined.

II. MATERIALS AND METHODS

Materials

Desized, scoured and bleached plain weave cotton fabric (220 ends/dm, 180 picks/dm, 120 g/m^2) from Nyanza Textiles Limited was used. Fresh stem bark of *Albizia coriaria* were collected from Busitema University compound, Busia-Uganda and brought to textile lab. Grey scale and blue dyed silk were used for color fastness rating.

Alum, Ferrous Sulphate, potassium dichromate, Ash water and Iron water were mordants used in dyeing. The following instruments were used; Analytical balance, Color data spectraflash photometer, manually operated Crockmeter, and Lauder-0-meter.

Fabrics pretreatment processes

Pieces of plain woven cotton fabrics with dimensions of (8 x 10 cm) each with an average weight of 1.41 g were scoured by washing them in sodium carbonate solution (0.5 gpl) and non-ionic detergent (Tweet® 80, 2 gpl) at 50ºC for 25 minutes keeping the material to liquor ratio at 1:40. The scoured fabrics were thoroughly washed with tap water and dried at room temperature.

Extraction of dye

Dye was extracted from dried and pulverized stem bark of *Albizia coriaria* by aqueous method. The leaves were soaked in distilled water (400 cm^3) in a beaker for four hours. The soaked plant materials were heated at 60°C for 30 min and temperature gradually raised to boiling temperature (90°C) and maintained at the boiling temperature for one hour to yield a dye extracts. The dye extract was left to stand for 30 min at ambient temperature and filtered [10]. The colored crude dye solution (150 cm^3) was diluted with distilled water (50 cm^3) and immediately used for dyeing.

Dyeing the cotton fabrics

Cotton fabrics were dyed using pre-mordanting, simultaneous and post-mordanting methods.

The scoured fabrics were soaked in clean water for 30 min prior to dyeing process.

In dyeing with pre-mordanting method, the pretreated cotton fabrics were soaked in a solution containing 10 % on weight of fabrics (o.w.f) of a mordant, at 60°C for 30 min with material-to-liquor ratio of 1:20. The fabrics samples soaked with mordant solutions were then dyed [11].

Dyeing with simultaneous mordanting method was done by putting the pretreated fabrics in a beaker (250 cm^3) containing 10% on weight of fabric (o.w.f) of mordant and 20% o.w.f of sodium sulphate. The pH of each dye solution were maintained between 6 and 8 with 2 - 5% w/w of acetic acid (40% solution) monitored by test papers during the dyeing process. A material to liquor ratio (LR) of 1:20 was used in all dyeing [12]. This was done separately using each of the selected mordants.

In post-mordanting dyeing of cotton fabrics, the pretreated fabrics were dipped in a dye bath (150 cm^3) and after 10 minutes, 20% on weight of fabric (o.w.f) of sodium sulphate was added. The dyeing was carried out for one hour at 50°C with intermittent stirring. The dyed samples were removed from dye bath and squeezed to remove excess dye. The dyed fabrics were then soaked in a mordant solution (100 cm^3) containing 10 % on weight of fabric (o.w.f) of a mordant at 60°C for 30 minutes with material to liquor ratio of 1:20 [10].

In all the above three methods, solutions for each of the selected mordants were separately made. The dyed samples were washed with soap solution (2 gpl) at 50°C for 10 minutes, rinsed with tap water and dried at room temperature.

Evaluation of color fastness

Wash fastness of the dyed samples were analyzed as per the standard method using a Launder-o-meter [13]. The wash fastness rating was measured using standard grey scale for loss of shade depth and staining.

Color fastness to dry rubbing and wet rubbing fastness were tested using a manually operated Crockmeter and grey scale [13]. Color fastness to light was evaluated with using MBTF Fade-o-meter. The fading of each sample was observed against the fading of blue wool standards (1-8) [13].

Color measurements

Color development and dye absorption potential of cotton fabrics were evaluated in terms of CIELab color coordinates; L (lightness), a (redness or greenness of color), b (yellowness or blueness of color), C (chroma) and H (hue angle), and K/S (color strength) values [14].

III. RESULTS AND DISCUSSIONS

Variable color shades were formed on the cotton fabrics dyed with extracts from the stem bark of *Albizia coriaria*. The variations in color shades were with respect to the mordants and mordanting methods employed.

Color fastness of the dye without the use of mordants

This was a control to determine color fastness of the dye without application of any mordant. As can be noticed in **Table 1** below, color fastness on the fabrics range from very good to excellent in the range of (4-5) and (5) against grey scale standard of 1-5 for washing and rubbing and respectively. A good light fastness grade of (4) against standard blue dyed wool of 1-8 was determined.

Table 1. Color fastness of the dye applied on cotton fabric without mordant

Wash fastness		Rub fastness				Light fastness
		Dry		Wet		
CC	CS	CC	CS	CC	CS	
4-5	3-4	5	4-5	5	3	4

CC=Color change, CS=Color staining

A slight staining of grade (3-4) was determined in washing with very slight and slight dry and wet rub staining of (4-5) and (3) respectively. Generally the color fastness obtained without application of mordant is suitable for dyeing cotton fabrics. From this piece of information it can be concluded that this dye is classified as a substantive dye. 'Substantive Dyes' are those that dye the fibers directly and 'Adjective dyes' are those dyes mordanted with a metallic salt [15].

Effects of mordants and mordanting methods on color fastness

In dyeing the cotton fabrics some selected mordants were used viz; alum, ferrous sulphate, and iron water. All these mordants were applied on the fabrics using pre-mordanting, simultaneous mordanting and post mordanting methods separately**. Table 2** below contains data for color fastness to washing, rubbing and light for the selected mordants using different mordanting methods. Color change and staining were determined for washing, dry and wet rub fastness.

Table 2: Color fastness of dyed cotton fabrics with *Albizia coriaria* dye using selected mordants and mordanting methods

Mordant 3% Conc	**Method of Mordanting**	***Wash fastness***		***Rub fastness***				***Light fastness***
		CC	**CS**	**Dry**		**Wet**		
				CC	**CS**	**CC**	**CS**	
Alum	PREM	**4***	**4-5**	**5**	**4-5**	**5**	**3-4**	**3**
	SM.	**3-4*R**	**3-4**	**5**	**4-5**	**5**	**4**	**3**
	POM	**4-5 W**	**4-5**	**5**	**3-4**	**5**	**3**	**3**
Ferrous sulphate	PREM	**4* R**	**4-5**	**5**	**3-4**	**5**	**3**	**6**
	SM	**4-5 R**	**4**	**5**	**3-4**	**5**	**3**	**5**
	POM	**4*R**	**3-4**	**5**	**3**	**5**	**1-2**	**6**
Iron water	PREM	**3-4**	**3-4**	**5**	**4-5**	**5**	**3**	**3**
	SM	**4**	**3-4**	**5**	**4-5**	**5**	**3**	**3**
	POM	**4R**	**3-4**	**5**	**4-5**	**5**	**3**	**5**

CC=Color change, CS=Color staining:
Remarks: *=stronger, *R=Stronger and Reddish, W=Weaker, R=Reddish.
PREM=Pre-mordanting, SM=Simultaneous mordanting, POM=post-mordanting

Alum mordant produced no observable change in wash and rub color fastness properties in comparison to that without a mordant but a reduced light fastness from rating (4) to (3) was recorded for all methods. The mordanting methods used had no significant effect on the color fastness properties in this case. However, there was a slight decrease in wash staining of (3-4) and (4-5) for pre- mordanting and post-mordanting methods respectively. In wash fastness with alum, pre and simultaneous mordanting recorded stronger grade (4*****) and stronger and reddish grade of (3-4*****R) with a weaker grade of (4W) registered for post-mordanting.

Ferrous sulphate mordant produced a significant improvement in light fastness from moderate (4) in control to good (5) for simultaneous mordanting and very good rating (6) for pre mordanting and post mordanting. There was no remarkable change in both wash and rub fastness however, in pre-mordanting and post-mordanting methods, the shades became reddish (4-5R) and stronger and reddish (4*****R).

The application of iron water mordant registered a poor light fastness from moderate (4) in control to fair (3) for both pre and simultaneous mordanting. However, post-mordanting registered a good light fastness of (5). For all mordanting methods, very good dry and wet rub fastness (5) were registered the same grade as in the control experiment. Wash fastness recorded for all the mordanting methods were inferior to the very good (4-5) in control with grades of moderate (3-4), good (4) and reddish (4R) for pre, simultaneous and post mordanting methods respectively. Iron water did not have any effect on staining from the use of all the mordanting methods.

In terms of color fastness rating obtained with the mordants used, post-mordanting method exhibited the best overall results. The mordant that recorded the best results in terms of fastness grades recorded are; ferrous sulphate, iron water, and alum in that order. The general improvement in fastness from the use of these mordants is as a result of the presence of strong metal coordination complexes formed inside the internal fiber structure between the mordant and dye fibers [16]. The iron species produced and deeper shades and alum produced lighter shades that varied with the method of application of mordant on the cotton fabrics. The deepest shades were registered with ferrous sulphate and iron water using post-mordanting method. A high quality colored fabric possesses an acceptable amount of color fastness rating of at least 3.0 on a five point grey scale [17]. Results of this study therefore demonstrates that dye from the stem bark of *Albizia coriaria* with light fastness rating of range (3) and (6) and wash and rub fastness grades of (3-4) and (5), meet minimum performance requirements for application on cotton fabrics.

Color characteristics based on CIELab color coordinates of dyed cotton fabrics.

The dyed fabrics were assessed for their color coordinates as reported in **Table 3** and the results are discussed with the aid of color space diagrams and surface color value graphs. Where L*=Lightness, a*=red-green, b*= yellow-blue,C*=chroma h^{o}= Hue angle, CV-SWL= Color value at single wave length and it is equivalent to K/S (Color strength) in terms of value.

Table 3: The CIELab color coordinates of cotton fabrics dyed with crude dye extracts from *Albizia coriaria*.

Mordant	Mordanting Method	L*	a*	b*	C*	h^o	CV-SWL
No mordant(control)	-	69.35	8.84	14.25	16.77	58.18	1.995
Iron water	PREM	53.41	3.75	8.59	9.37	66.4	3.667
	SM	60.98	3.82	10.17	10.86	69.41	2.452
	POM	53.38	4.07	10.47	11.23	68.75	3.713
Alum	PREM	70.61	6.6	17.15	18.37	68.96	1.986
	SM	69.48	6.51	14.07	15.5	65.18	1.825
	POM	67.86	7.27	16.43	17.97	66.13	1.938
Ferrous Sulphate	PREM	37.5	3.47	7.53	8.29	65.23	10.06
	SM	40.16	3.49	8.63	9.31	68	8.641
	POM	6.57	19.71	11.17	22.65	29.54	14.99

PREM= pre-mordanting, SM= simultaneous mordanting, POM= post-mordanting

As can be noticed from **Table 3** for pre-mordanting method, the color strengths (**CV**) recorded were; (3.667), (1.986), (10.06) for iron water, alum and ferrous sulphate respectively with control registering (1.995). In this case ferrous sulphate had the best color strength followed by iron water and alum had the lowest color strength falling below the control. In simultaneous mordanting methods color strength registered were (2.452), (1.825) and (8.641) for iron water, alum and ferrous sulphate respectively. Ferrous sulphate had the best color intensity followed by iron water. Alum had an inferior color strength which is even lower than the control. The post mordanting method gave the following color strength; (3.713), (1.938) and (14.99) for iron water, alum and ferrous sulphate respectively. In this case ferrous sulphate gave the highest color strength followed by iron water and alum had the lowest color strength. In all the mordanting methods alum had no positive contribution on color strength in fact its performance is below that in the control. The performance of the mordanting methods in terms of color strength is in the order; post, pre and simultaneous mordanting.Post mordanting method is therefore the method to be adopted in the application of dye from the stem bark of *Albizia coriaria* on cotton fabrics.

Dyes from *Albizia coriaria* produced darker shades (L < 70) with ferrous sulphate and iron water in the range of (37.5-40.16) and (53.38-60.98) respectively. Alum exhibited lighter shades ranging from (67.86-70.61). With all mordants, post- mordanting method produced lower L values hence deeper shades. Color shades formed by post-mordanting exhibited the highest degree of color saturation C of (11.23), (17.97) and (22.65) for iron water, alum and ferrous sulphate in that order with the exception of alum where pre-mordanting had a higher value of C (18.37). The net effect of alum high value of chroma and lightness is reflected in its high brilliant appearance.

Fabrics dyed with *Albizia coriaria* exhibited only positive "a" value for all the mordanting methods with post-mordanting of ferrous sulphate having the highest "a" value of (19.71) as shown in **Table 3**. The values of "a" and "b" placed the dyed fabric with *Albizia coriaria* extract in the red-yellow quadrant of the color space diagram as shown in **Figure 1**.

Post-mordanting with ferrous sulphate gave the lowest hue angle h^o value of (29.54) redness of color. Most mordanting methods gave hue angle h^o > 45° implying yellowness of color. The shades are all closer to yellow than red.

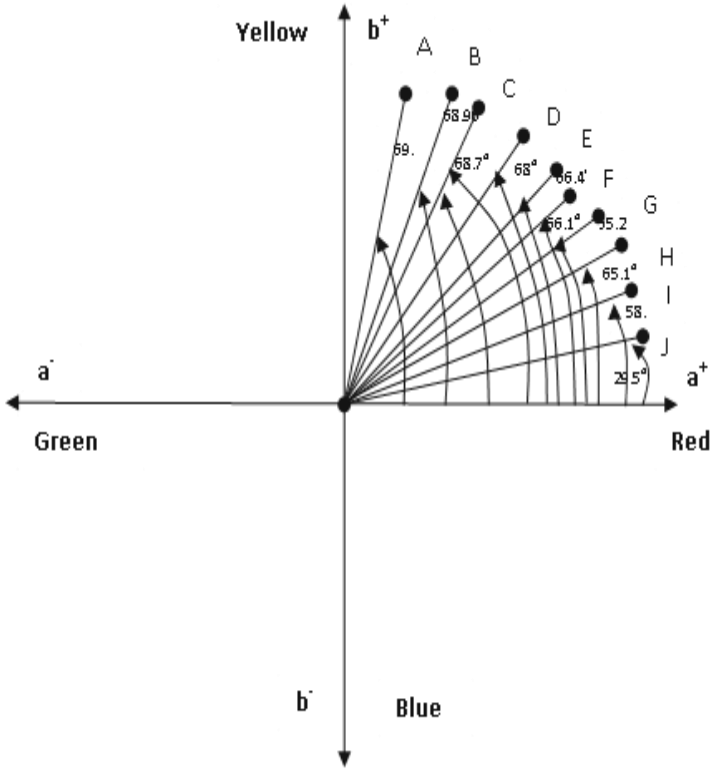

Figure 1: Location of colored fabric samples in the a-b color space diagram.

Key

A: simultaneous Iron water, B: Pre Alum, C:Post Iron water, D:simultaneous Ferrous sulphate, E: Pre Iron water, F: Post Alum, G:Pre Ferrous sulphate, H: simultaneous alum, I:No mordant, J:Post ferrous sulphate.

Control fabrics also gave a hue angle H (58.18) falling within the range of the mordanted fabrics. The mordanting methods used had no significant influence on the redness and yellowness of color shades formed.

IV. CONCLUSIONS

Dyes extracted from the stem bark of *Albizia coriaria* yielded various color shades with different mordants. The cotton fabrics dyed without the use of mordants exhibited a very good wash fastness of (4-5), a excellent dry and wet rub fastness of (5), and a moderate light fastness of (4). The dye is therefore substantive dye with good color fastness property. The application of mordants yielded various color shades with different mordants and mordanting methods without any observable improvement in dry and wet rub fastness however, with washing the shades turned redder. The formation of a single color with variable shades depending on mordant used classifies the dye as monogenetic dye. Upon application of mordants, there was general drop in light fastness with alum and iron water. Generally post-mordanting method recorded an overall best light fastness performance with ferrous sulphate and iron water. Color strength was enhanced by the application of post-mordanting methods across all mordants used but, more brilliant color shades was recorded for simultaneous mordanting method. The mordanting method used no significant influence on the redness and yellowness of color. It can be concluded that, to achieve excellent fastness and good color strength with dye from *Albizia coriaria*, post-mordanting is a method of choice.

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The preferred spelling of the word “acknowledgment” in American English is without an “e” after the “g.” Use the singular heading even if you have many acknowledgments.

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