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Investigation on the Effect of Natural Mordants on Dyeing Properties of Cotton Fabric with Natural Dye

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ABSTRACT : This research concerned with the application of natural dye and natural mordant on cotton substrate and analyzing on the properties of dyed cotton fabric. The main aim of research is to reduce the application of synthetic dyes which release enormous amount of hazardous chemicals in the environment during production and subsequent use. The objectives of this research are to apply the natural dye (Turmeric Powder) and natural mordant such as Aloe Vera Gel, Lemon Juice and Pseudo Stem Sap on cotton fabric, to analyze the physical properties and colour fastness properties of dyed fabrics and to investigate the shade variation of dyed fabrics by using CIE L* a* b* colour system . Natural dye and natural mordants used in this research can be easily sustainable obtained everywhere in Myanmar.

Keywords: colour fastness properties, CIE L* a* b* colour system, natural dye, natural mordant, physical properties

I. INTRODUCTION

Nature is full of fascinating colors and people had been exploiting them for dyeing garments, using them in food and many other items of the daily use. Today the protection of environment has become a challenge for the chemical industry worldwide and the water pollution caused by synthetic dyes in particular, the control of effluent continue to be a problem. All the colouring matters were derived directly from vegetable or animal sources, until the advent of synthetic dyes.

Natural dyes cover all the dyes derived from plants, insects and minerals that is derived from natural sources without chemical processing. Natural dyes are biodegradable also, unlike the synthetic dyes these do not pose a problem of pollution for waste which remains after the dyeing process these are easily absorbed by the soil. Natural dye and natural mordant are favorable to ecology as plants, shrubs and trees constitute the main source. Natural dyes are safe and eco-friendly as they are found to be free from hazardous chemicals. Therefore, their commercial use shall definitely minimize the health hazards caused by the use of synthetic dyes.

II. MATERIALS

2.1. Natural Dye

Natural dyes are deep and soft in color shades when compared with synthetic dyes. And they are useful for human health because they have antibacterial, insecticidal and healthy properties, which are due to the origin of them- extracted from herb plants. Besides, with the increase of the worldwide concern for the environmental circumstances, many are anxious for the possibility of the natural dyes because they can overcome the defects of synthetic dyes such as harmfulness to human body, pollution and wastewater. But natural dyes show very low dye exhaustion to cotton fibre compared with silk or wool fibres, and satisfying results have not been acquired till now even though many dyeing methods such as repeat dyeing and mordant treatment have been done to overcome this problem.

2.1.1. Turmeric

Turmeric is a flowering plant, Curcuma longa of the ginger family, Zingiberaceae. The plant is a perennial, rhizomatous, herbaceous plant native to the Indian subcontinent and Southeast Asia. The rhizomes are used fresh or boiled in water and dried, after which they are ground into a deep orange-yellow powder commonly used as a coloring and flavoring agent in many Asian cuisines, especially for curries, as well as for

dyeing.

Turmeric powder has a warm, bitter, black pepper-like flavor and earthy, mustard-like aroma. Turmeric powder is about 60–70% carbohydrates, 6–13% water, 6–8% protein, 5–10% fat, 3–7% dietary minerals, 3–7% essential oils, 2–7% dietary fiber, and 1–6% curcuminoids. The golden yellow color of turmeric is due to curcumin. It also contains an orange-colored volatile oil. Turmeric makes a poor fabric dye, as it is not very light fast, but is commonly used in Indian clothing, such as saris and Buddhist monks's robes.

2.2. Mordants

Natural dyes are substantive, needing no mordant or adjective requiring a mordant. The majority of natural dyes need a chemical in the form of metal salt to create an affinity between the fibre and the pigment.

Mordanting of the textile material is to improve the colour yield in the development of shade and to help fixation of the colouring molecule to the substrate as a link; in effect mordanting should also improve the fastness properties against light, temperature, humidity, atmospheric contaminants and washing fastness during subsequent processing stages and the product while in use.

2.2.1.Role of Mordant in Vegetable dyeing

Most of the vegetable dyes require the use of mordants prior to dyeing of textile materials. In fact the process of mordanting prepares the textile materials to receive the dyestuff. Mordants are supported to assist the process of dyeing and should not affect the physical and chemical characteristics of the textile materials. They should thoroughly penetrate the textile material for successfully dyeing operations. If the mordants are present in superficial stages then dyeing shade development will be uneven. Mordants are classified into,

i. Metallic salts (alum, potassium dichromate, ferrous sulphate, copper, etc)
ii. Vegetable mordants (myrobolan and sumach, etc)
iii. Oil and oil based mordants

2.2.2.Aloe Vera

Aloe vera is a succulent plant species of the genus Aloe. An evergreen perennial, it originates from the Arabian Peninsula but grows wild in tropical climates around the world and is cultivated for agricultural and medicinal uses. It is found in many consumer products including beverages, skin lotion, cosmetics, or ointments for minor burns and sunburns. Aleo vera gel is used as mordant in textile dyeing. Aloe vera leaves contain phytochemicals under study for possible bioactivity, such as acetylated mannans, polymannans, anthraquinone C-glycosides, anthrones, and other anthraquinones, such as emodin and various lectins. The leaves are thick and fleshy, green to grey-green, with some varieties showing white flecks on their upper and lower stem surfaces. The margin of the leaf is serrated and has small white teeth.

2.2.3. Lemon

The lemon, Citrus limon (L.) Osbeck, is a species of small evergreen tree in the flowering plant family Rutaceae, native to South Asia, primarily North eastern India. The tree's ellipsoidal yellow fruit is used for culinary and non-culinary purposes throughout the world, primarily for its juice, which has both culinary and cleaning uses. The pulp and rind are also used in cooking and baking. The juice of the lemon is about 5% to 6% citric acid, with a pH of around 2.2, giving it a sour taste. The distinctive sour taste of lemon juice makes it a key ingredient in drinks and foods such as lemonade and lemon meringue pie. Lemons contain numerous phytochemicals, including polyphenols, terpenes, and tannins. Lemon juice contains slightly more citric acid than lime juice (about 47 g/l), nearly twice the citric acid of grapefruit juice, and about five times the amount of citric acid found in orange juice.

2.2.4. Pseudo Stem Sap

Banana is one of the most well-known and useful plants in the world. Almost all the parts of this plant, that are, fruit, leaves, flower bud, trunk, and pseudo-stem, can be utilized. Bananas are widely produced and abundant natural resources in tropical and subtropical countries in the world.

Banana pseudo stem sap (BPS) has been extracted from the outer sheath of pseudo stem of banana tree (Musa Cavendish). It looks like colourless clean water immediately after extraction. However, with the passage of time, it slowly turns into a light khaki colour due to the oxidation of phenolic rings present in it. As BPS contains minerals like sodium, potassium, magnesium, and calcium, it can be used as an energy booster for the sportsmen or as an energy drink for alike applications. It has been reported that the alkaline fraction of BPS can be used as an anticorrosive agent for concrete steel, as it is composed of compounds like inorganic materials, polyphenol oxidase, peroxidase and phenolic aromatic ring. As far as the textile application is concerned, BPS has been used as an active ingredient for natural dye, mordant, UV protective and flame retardant formulation.

III. METHOD

3.3 Fabric Analysis

Physical properties of cotton fabric like fabric weight, fabric stiffness and fabric breaking strength are determined according to the respective ASTM standards. The sample fabric is conditioned in the standard atmosphere having relative humidity of (65±2) % R.H and a temperature of (20±2) °C for 24 hours. These tests are performed at Textile Testing and Quality Control Laboratory, Department of Textile Engineering, Yangon Technological University. The summary of physical properties test results is presented in Table 4.1.

3.4. Preparation of Bleached Cotton Fabric

Cotton is the backbone of the world's textile trade. Many of our everyday textile fabrics are made from cotton. Cotton has been used for apparel purposes because of its well-known advantages such as ability to take up a wide range of dyestuff, low cost of production and comfort during wear. So, cotton fabric is selected as substrate to apply the dyestuff in this research. Bleached cotton fabric is collected from local market.

Before the dyeing process the bleached cotton fabric is cut into 10″x72″ and weighed. And then it is soaked in water for several hours. The purpose of this process is to remove the impurities, to impart certain desirable water absorbency, to improve the appearance of fabric (whiteness) and to make it suitable for subsequent process like dyeing. After soaking process, the sample fabric is squeezed and mounted to the jigger machine to perform the dyeing operation with natural turmeric dye and natural mordant.

3.5. Dyeing and Mordanting the Cotton Fabric

In the preparation of dye bath, 5 % of turmeric dye powder (o.w.f) is pasted with warm water and then cold water is added to completely dissolve the dye powder in solution. Material to liquor ratio used in this experiment is 1:15. One sample is dyed without mordant to compare the properties and colour strength with the dyed sample with mordant. After dissolving the dye powder in solution, the mordant (aleo vera gel/ lemon juice/ pseudo stem sap) 10%, 20%, 30% is added to the dye solution. Simultaneous mordanting and dyeing method is used in this study. Dyeing and mordanting conditions are shown in Table 3.1. The fabric is dyed in jigger machine at 80° C for 45 minutes. After dyeing process, the dyed fabric is rinsed with cold water to remove the unfixed dye and squeezed out by hand. And then the fabric is dried at room temperature.

Table. 3.1 Dyeing Condition

Sr. No.	Sample Code	Turmeric Dye (%)	Mordant	Mordant (%)	M:L	Dye Solution (pH)	Dyeing Time (min)	Dyeing Temp (°C)
1	T	5	-	-	1:15	7	45	80
2	A_{10}		Aloe Vera Gel	10%		6		
3	A_{20}			20%		6		
4	A_{30}			30%		6		
5	L_{10}		Lemon Juice	10%		3		
6	L_{20}			20%		3		
7	L_{30}			30%		3		
8	P_{10}		Pseudo Stem Sap	10%		6-7		
9	P_{20}			20%		6-7		
10	P_{30}			30%		6-7		

3.6. Physical Properties of Dyed Cotton Fabrics

Dyeing the cotton fabric with natural dye and natural mordant can affect the physical properties of the samples. After dyeing process physical properties of dyed fabric such as fabric weight, fabric stiffness and fabric breaking strength are determined according to the respective ASTM standards. Comparison of physical

properties of dyed and undyed fabric is shown in Table 4.1.

3.7. Measurement of Dye Absorption and Colour

X-rite spectrophotometer is used to measure the spectroreflectance and adsorption concentration of surface (K/S) of dyed cotton fabrics and CIE L* a* b* colour system is applied for the achievement of colour values such as lightness, chroma, hue angle, red colour (+a) or green colour (-a), yellow colour (+b) or blue colour (-b)**.** Colour values of dyed sample fabrics with and without mordant can be observed in Table 4.2.

3.8. Determination of Colour Fastness Properties on Dyed Cotton Fabrics

Colour fastness is the property of pigment or dye to retain its original hue, especially without fading, running, or changing when wetted, washed, cleaned; or stored under normal conditions when exposed to light, heat or other influences. There are many types of fastness properties such as washing, light, crocking, and abrasion, gases in atmosphere, frosting, perspiration and heat. In this study, light fastness, washing fastness and rubbing fastness tests are performed because they are normally exposed in textile manufacturing and in daily use.

3.8.1. Determination of Light Fastness Properties on Dyed Cotton Fabrics

Light fastness refers to the ability of the fabric to withstand the sunlight and the resistance of the sunlight depends on the intensity of the light, inherent properties of the fabric, season, altitude and distance from the equator. In determining the light fastness of dyed fabric, the principle is mainly based on ISO-105 A02. 1987. The fabrics are tested in Acme type fading test machine and light fastness grade of dyed fabrics are shown in Table 4.3.

3.8.2. Determination of Washing Fastness Properties on Dyed Cotton Fabrics

After dyeing process, washing is carried out in accordance with ISO Test No.3. Colour fastness to washing is ability of the fabric to withstand the effect of laundering. In this experiment Scrub O Meter washing machine is used to evaluate colour fastness to washing with the help of grey scales. The washing of fabric results in the removal of dye, therefore staining can occur, in order to determine the staining; a white fabric is attached to the specimen being tested for colour fastness to washing. Test results are shown in Table 4.3.

3.8.3. Determination of Rubbing Fastness Properties on Dyed Cotton Fabrics

Rubbing color fastness refers to the ability to sustain original color of dyed fabrics when rubbing. Dry rubbing color fastness refers to the situation of fading and staining of dyed fabric when rubbed with a standard white cloth. Wet rubbing color fastness refers to the situation of fading and staining of dyed fabric when rubbed with a standard white cloth which water content is 95% to 105%. The evaluation of Rubbing color fastness depends on the degree of staining of white cloth. After testing, the white cloth is compared to staining sample cards to measure staining fastness. The friction fading of fabric is to make dye fall off caused by friction. Wet rubbing is influenced by both external force and water, so it is about one level lower than dry rubbing.

The rubbing off of colour is called as crocking. Test procedure is performed by AATCC Test Method 8-1996 and motor type crock meter is used to find the colour fastness to crocking. This instrument has a finger covered by a white cotton fabric which would rub against the specimen. Dry and wet rubbing test are performed in this study. The wet test is a severe test since moisture helps in removal of dyes. Test results of rubbing are described in Table 4.3.

IV. RESULTS AND DISCUSSIONS

4.1 Determination of the Physical Properties of Cotton Fabric

The natural dyeing can affect the physical prolperties of the fabric. So the investigation on the physical properties of dyed fabrics is also performed.

According to the fabric weight test results in Table 4.1, the weight of all dyed fabrics increases when comparing with the undyed fabric. Among the dyed fabrics with mordant, the range of dyed samples with Pseudo stem sap from 112.49 to 115.20, so they give the heavier weight than other samples.

Based on the summary test results, the overall flexural rigidity of the all dyed samples is larger than the undyed fabric. The higher overall flexural rigidity value, the stiffer the fabric. Among the sample fabrics, P_{10}, P_{20} and P_{30} are stiffer than the other dyed fabrics. This indicated that the Pseudo stem sap mordant give the stiffer effect than the other.

According to the test results, the breaking strength of the sample fabrics dyed without mordant (T) and all dyed fabric mordanted with Aleo vera gel (A_{10}, A_{20} and A_{30}) and Pseudo stem sap P_{30} increase than the undyed sample in warp direction. Breaking strength of all the dyed samples mordanted with lemon juice

decreased than the undyed fabric. Lemon juice contains citric acid which can also cause the degradation of cotton. Therefore, precautions in terms of concentration of acid, time of treatment and temperature must be taken to avoid loss of strength of cotton fabric.

In the filling direction, the breaking strength of all dyed sample fabrics (with and without mordant) is increased when compared with the undyed fabric. The best breaking strength in filling direction is sample A_{30} which is mordanted with 30 % concentration of aleo vera gel.

Table 4.1 Summary of the Physical Properties Results of Undyed and Dye Fabrics

Sr. No.	Sample Code	Parameters Test Results (Mean Values)			
		Fabric weight (g/m^2)	Breaking Strength (kgf)		Overall Flexural Rigidity (mg-cm)
			Warp	Filling	
1	C	98.70	48.10	21.50	11.58
2	T	109.27	54.40	26.80	13.51
3	A_{10}	109.91	49.70	23.00	15.26
4	A_{20}	112.21	49.10	26.90	13.57
5	A_{30}	114.06	49.10	28.00	15.19
6	L_{10}	110.29	43.50	23.40	13.81
7	L_{20}	111.14	43.50	23.40	15.58
8	L_{30}	112.58	41.86	23.60	15.58
9	P_{10}	112.49	47.35	25.70	16.87
10	P_{20}	114.01	42.70	25.40	17.79
11	P_{30}	115.20	51.20	26.50	16.99

4.2. Determination of Coloure Developed on Dyed Cotton Fabrics

According to the test results shown in Table 4.2, L* values of all dye fabrics lie between 87.77 and 90.21. So the colour of dyed fabrics seen lighter in colour. But the L* value of dyed fabric without mordant (Sample T) is largest, this indicate that the sample fabric T is lighter than the other dyed fabrics with mordants.

Base on the resultant data of a* and b* values, all dyed samples indicate the yellow colour in shade. Among them, the dyed sample fabrics with lemon juice mordant give the more yellower and brighter in color than the other because the b* vales of those are larger than the others.

However, color of dye sample T, A_{10}, A_{20}, A_{30}, P_{10}, P_{20} and P_{30} or except Lemon Juice mordanted fabrics indicate the pale greenish-yellow due to the negative values of a*. According to the visual observation, the dyed sample fabrics mordanted with lemon juice give the more yellower and brighter in color and the other are pale greenish yellow in color. So visual observation and result of actual measurement with instrument are identical. Moreover, Chroma values of dyed sample fabric with lemon juice mordant larger than the other samples, this represents the more saturation in yellow color than the other. Among them, the Chroma of L_{20} is the highest. From the color strength point of view, K/S value of L_{20} is also highest. In addition colour difference (ΔE) from standard fabric T is largest. Color of Dyed Cotton Fabrics is shown in Appendex A.

Table 4.2. Colour Values and Colour Strength

Sr. No.	Sample Code	CIELAB					DE*	K/S
		L*	a*	b*	C*	h°		
1	T	90.21	-5.22	47.55	47.83	96.26	0.00	0.50
2	A_{10}	89.55	-4.25	56.05	56.21	94.34	8.58	0.72
3	A_{20}	89.63	-3.75	56.26	56.38	93.81	8.85	0.74
4	A_{30}	88.81	-2.50	59.64	59.69	92.40	12.47	0.90
5	L_{10}	88.25	0.92	75.59	75.59	89.30	28.77	1.93
6	L_{20}	88.58	1.00	78.65	78.66	89.27	31.76	**2.12**
7	L_{30}	88.26	0.73	72.22	72.22	89.42	25.45	1.72
8	P_{10}	89.36	-3.27	48.00	48.11	93.90	2.17	0.57
9	P_{20}	89.18	-3.66	55.26	55.38	93.79	7.94	0.73
10	P_{30}	87.77	-1.97	55.37	55.41	92.03	8.82	0.84

4.3. Determaination of Fastness Properties on Dyed Cotton Fabrics

Washing fastness test is carried out in accordance with ISO Test No. 3. Change in colour of dyed sample and staining on adjacent white sample are assessed by comparing with grey scale and test results are

shown in Table 4.3. According to the test results, sample T (dyed with turmeric dye only) give the fastness Grade 2 which is considerably change in shade and means poor in washing fastness property. Comparing the shade change of dyed fabrics without and with different mordants, all of the sample show the Grade 3 which is fair in shade change or noticeable changed except samples A_{20} , A_{30}, P_{10}, and P_{20}. In terms of staining, there are very slight staining on control fabric showing fastness to good for all dyed fabrics with and without mordant.

Table 4.3 Colour Fastness Properties

Sr.No.	Sample Code	Washing		Light	Rubbing	
		Change in Shade	Staining		Dry	Wet
1	T	2	4	4	5	3
2	A_{10}	3	4	3	5	3
3	A_{20}	2	4	3	5	3
4	A_{30}	2	4	3	5	3
5	L_{10}	3	4	3	5	2
6	L_{20}	3	4	3	5	2
7	L_{30}	3	4	3	5	2
8	P_{10}	2	4	3	5	3
9	P_{20}	2	4	3	5	3
10	P_{30}	3	4	3	5	3

According to the test results, light fastness of sample T (dyed with turmeric dye only) is grade 4 which is very slight fading. But dyed fabric with aloe vera gel, lemon juice and pseudo stem sap mordant give grade 3 which is fair or moderate fading. So natural mordants used in dyeing can affect the light fastness properties of dyed fabric. Dry rubbing fastness of all dyed samples (with and without mordant) is excellent. Wet rubbing fastness of all dyed samples with lemon juice mordant is poor because the grade is 2 and the other samples are the fair in grade and moderate staining on white sample.

V. CONCLUSION

From the study of "Investigation on the Effect of Natural Mordants on Dyeing Properties of Cotton Fabric with Natural Dye"**,**the following conclusions can be drawn.

1. The breaking strength in warp direction of dyed fabrics with mordant decreases when compared with dyed fabric without mordant (T). Among the dyed fabrics, sample L_{10} ,L_{20}, and L_{30} have lower strength than others. This is due to the acidic condition of dye solution (pH -3). Lemon juice contains citric acid which can also cause the degradation of cotton.
2. All of the dyed fabric is stiffer than undyed fabric. Among them dyed fabrics with pseudo stem sap mordant are stiffer than the other.
3. The weight of all dyed fabric increased when compared with the undyed fabric.
4. The colour of all dyed fabric is attractive and brighter in colour. Among them colour strength of L_{20} is largest which is treated with 20% concentration of lemon juice mordant.
5. As for washing fastness properties, the colour change in shade of all dyed sample with lemon juice mordant are graded as fair.
6. From the point of rubbing fastness properties, dry rubbing fastness properties for all dyed samples are excellent and wet rubbing fastness properties are significant staining in dye samples with lemon juice mordant.
7. According to the theory, turmeric makes a poor fabric dye, as it is not very light fast. In practical, light fastness results show poor grade, so it can be concluded that natural mordants such as aloe vera gel, lemon juice and pseudo stem sap should not be used in turmeric dyeing with simultaneous dyeing and mordanting. Other mordanting methods such as premordanting and post mordanting method should be carried out as future work.
8. Dyeing time, dyeing temperature, dye concentration and mordant concentration also affect the dyeing. So it is suggested to study the effect of various dying time, dyeing temperature and concentrations.
9. Turmeric dyed fabric with natural mordant can be used in apparel because they do not contain toxic chemical which are harmful to human skin. Moreover, cotton is comfort in during wear, soft, cool, absorbent and breathable; it is suitable in garment which is close to the body. It can be used in household items which do not require frequent washing, but it should not be used in curtain because of poor fastness properties and stiffness.

10. The advantage of natural dyeing process is simple and economical as no chemical and energy is required.

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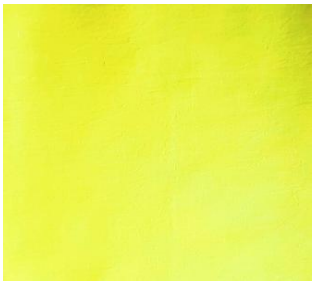
Appendix A
Colour of Dyed Cotton Fabrics

T

A_{10}



A_{20}

A_{30}

L_{10}

L_{20}

L_{30}

P_{10}

P_{20}

P_{30}