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Dyeing Cotton, Silk and Wool Yarn with Extract of *Garcinia Mangostana* Pericarp

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ABSTRACT

Aqueous extract of pericarp of Garcinia was prepared by sonicator for quick extraction of the colorant and has been used for dyeing cotton, silk and wool yarn. 1-2 % of premordanting with metal salts of Al, Sn, Fe, Cr and Cu was done. Fe, cu and Cr are best suited mordants for garcinia. The hue color ranged from camel brown to dark chocolate brown. The color strength K/S has been found to be very good in dyed samples. The fastness properties have also been evaluated and were found to be well above the acceptable limits.

Keywords: Garcinia Mangostana, natural dye, cotton, wool, silk, commercial dyeing

Introduction

The *Garcinia mangostana* is a tropical evergreen tree, growing abundantly in Srilanka. The tree grows from 7 to 25 meters tall. The rind or pericarp of the fruit is deep reddish purple when ripe. The fragrant flesh is sweet and creamy, citrusy with a touch of peach flavor. The outer shell of the fruit, its exocarp, typically 4-6 cm in diameter, and contains astringent phytochemicals which discourage infestation by insects, fungi, plant viruses and bacteria. The same phytochemicals are pigments giving the exocarp its characteristic purple color, including phenolic acids, also called phenols. These pigments have antioxidant properties. Isolation of exocarp pigments has permitted their identity to be revealed as xanthones, mainly garcinol and mangostin[1], which, as phenolics, make the exocarp highly astringent and inedible as shown in figure-1.

Figure-1-Fresh Fruit of Garcinia

Garcinia is cultivated and sold in Srilanka, An ultra-tropical tree, the garcinia must be grown in consistently warm conditions, as exposure to temperatures below 4°C [2] will generally kill a mature plant. Thus the Sri Lankan climatic condition suits the growth of the tree.

2. Materials and Methods

2.1 Materials

Pericarp of the fruit chosen: Dried Exo or pericarp of the edible fruit of *Garcinia mangostana* sourced from Srilanka is shown in figure-2.

Figure-2-Dried Exo or pericarp of the fruit of *Garcinia*

Studies on cotton: The cotton fabric of 105 g/m^2 (warp-30, weft-20) was used for dyeing.
Studies on silk: The munga silk of GSM-45 fabric was used for dyeing.
Studies on wool: Commercially bleached wool yarn supplied by Jaypee(pure new wool) were used for dyeing.

2.1.1 Chemicals used: Metallic salts such as alum, stannic chloride, stannous chloride were supplied by S.D.Fine and ferrous sulphate, potassium dichromate and copper sulphate were supplied by Loba Chemie.

2.2. Methods

2.2.1. Extraction of colorant: **Extraction of the dye:**

Sonicator extraction: Dry pericarps(100gms) from the Garcinia fruit were crushed and dissolved in distilled water(500 ml) and heated to (650C) in a beaker kept in sonicator bath for quick extraction for 30 mins, after this the extract was filtered. The extract was concentrated on a rotatory evaporator till the volume became half and then used for dyeing(approximately 250 ml).

Conventional extraction: The dried pericarps (100gms) were crushed and dissolved in distilled water (500ml) and allowed to boil in a beaker kept over water bath for quick extraction for 3 hour. All the color was extracted from pericarp by the end of 3 hours. The solution was filtered, evaporated to half volume (250 ml) and then used for dyeing purpose.

2.2.2. Identification of extracted dye: The extracted dye was identified by characterization through various techniques.

Ultra violet-visible spectroscopy: The extracted dye was dissolved in a suitable solvent system (water) and scanned through UV-Visible spectrophotometer (Hελious α UV lamda).

Fourier transform – infra-red spectroscopy: FT-IR of extracted and purified dye were recorded on Vertex 70 model of Bruker.

2.2.3 Fastness Testing of dyed samples :
Xenoster: Used to test the light fastness of the dyed fabric.
Wash wheel: Thermolab model**:** Used to test the washing fastness of the dyed fabric.
Perspirometer: Sashmira Model*:* Used for the testing of perspiration fastness of the dyed fabric.
Crock meter: Ravindra Engg. Model: Used for testing the rubbing fastness of the dyed fabric.
Color Matching system: The reflectance of dyed fabrics was measured on a Premier Colorscan.

2.2.4. Scouring of Material: Cotton, silk and wool were separately washed with solution containing 0.5 g/L sodium carbonate and 2 g/L non-ionic detergent (Labolene) solution at 40-45° C for 30 min, keeping the material to liquor ratio at 1:50. The scoured material was thoroughly washed with tap water and dried at room

temperature. The scoured material was soaked in clean water for 30 min prior to dyeing or mordanting.

2.2.5. Mordanting: Natural dyes require chemical in the form of metal salts to produce an affinity between the fabric (cotton and silk) as well as wool yarn and the pigments and these chemicals are known as mordants. Pretreatment with tannic acid(4% owf) was carried out for cotton samples only. This process was not required for silk and wool. Accurately weighed sample was treated with different metal salt (1-2% owf), only premordanting with metal salts was carried out before dyeing. The mordant was dissolved in water to make liquor ratio 1:50. The wetted sample was entered into the mordant solution and then it was brought to heating. Temperature of the solution was raised to 60°C over half an hour and left at that temperature for another 30 minutes. The mordanted material was then rinsed with water thoroughly, squeezed and dried. Mordanted sample should be used immediately because some mordants are very sensitive to light.

2.2.6. Dyeing: The cotton fabric samples were dyed with dye extract, keeping M:L ratio as 1:40 at its original pH of the dye extract(6.5), only in the case of silk and wool dyeing the pH was maintained at 4 by adding buffer solution (sodium acetate and acetic acid). The dye extract was prepared by as mentioned in 2.2.1 keeping (M:L:: 1: 40). The dyed material was washed with cold water and dried at room temperature, it was then dipped in brine for dye fixing.

2.2.7. Measurement of Color Strength
The color yield of both dyed and mordanted samples were evaluated by light reflectance measurements using Premier Colorscan machine.
The color strength (K/S value) was assessed using the Kubelka-Munk equation [3,4]:

$$K/S = (1-R)\ 2/2R$$

Where K is the sorption coefficient, R is the reflectance of the dyed fabric and S is the scattering coefficient. The CIELab values were determined for all the samples investigated here.

2.2.8. Fastness testing
The dyed samples were tested according to Indian standard methods[5]. The specific tests were: color fastness for light, **IS-2454-85**, color fastness to rubbing, **IS-766-88**, color fastness to washing; **IS-687-79**, and color fastness to perspiration, **IS-971-83.**

3. Chemical composition of the colorant:

Colorant in the dried pericarp of Garcinia: The main colorant found in the dried pericarp of the Garcinia fruit is Mangostin [6] as shown in figure-3.

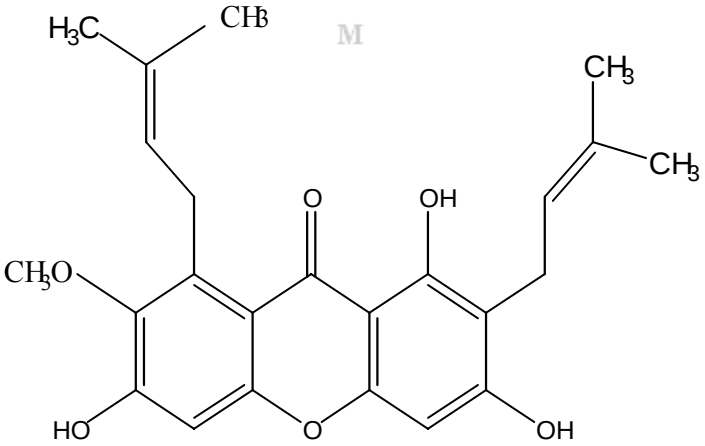

Figure-3-Mangostin

4. Results and Discussion

4.1. Preparation and optimization of aqueous extract of *Garcinia mangostana*

The dried pericarps of the fruit of Garcinia were found to give color in hot water very easily by sonication. Increasing the quantity of dried pericarp from 2gm to 20 gm per 100 ml water boiled for 30 min is accompanied with the increase in color strength and depth in color hue.

4.2. Spectral analysis of the dye extract:

Methanolic extract was also prepared to record UV-Visible spectrum as shown in figure-4 and 5. FT-IR spectrum was recorded of the dry exocarp powder as shown in Figure-6.

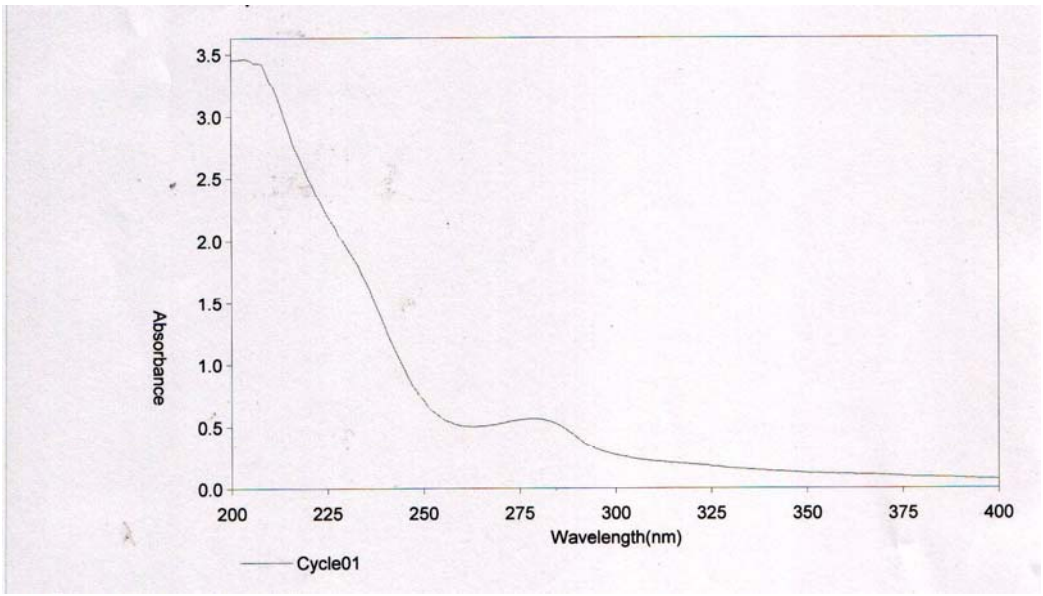

Figure-4- UV spectrum of aqueous extract of Garcinia

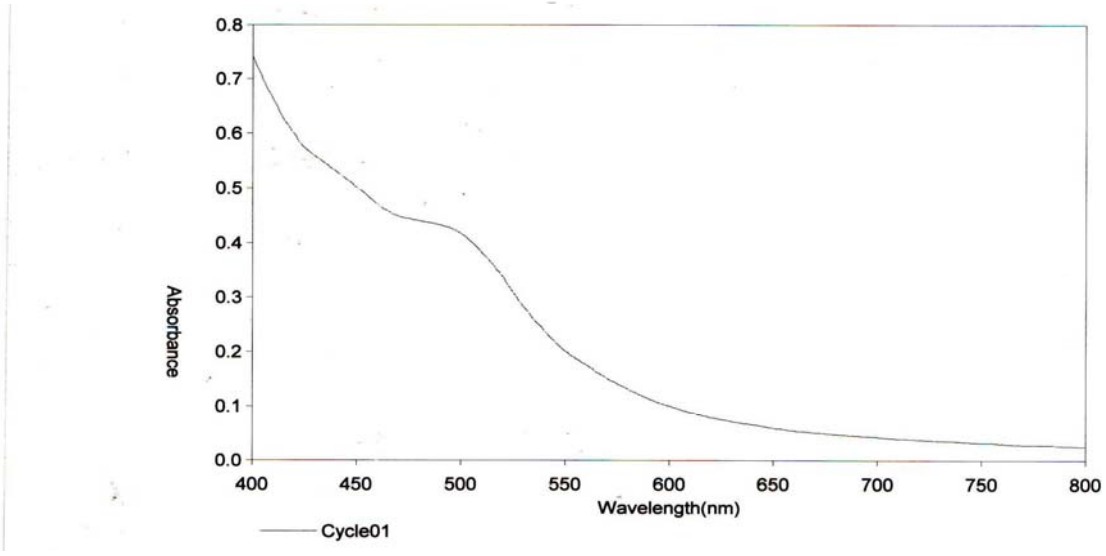

Figure-5- Visible spectrum of aqueous extract of Garcinia

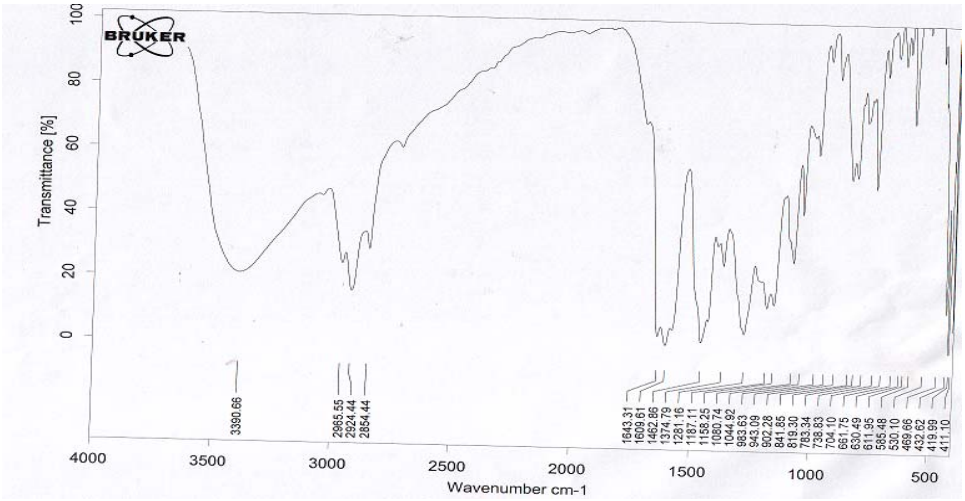

Figure-6- FT-IR spectrum of aqueous extract of Garcinia

4.3. Optimization of mordants with K/S and Color hue changes

Different mordants are used in 1-2 % keeping in mind the toxicity factor of some mordants. Varied hues of color can be obtained from premordanting the cotton, silk and wool yarn[7] with $FeSO_4$, $SnCl_2$, $CuSO_4$, $SnCl_4$, $K_2Cr_2O_7$ and alum were dyed by aqueous extract of pericarp of garcinia as shown in the figure-1, the different mordants not only cause difference in hue color and significant changes in K/S values but also L* values and brightness index values. The best values are obtained with ferrous sulphate and the order of reactivity is Fe> Cr > Cu >> Al >Sn (IV) > Sn (II) for cotton samples as shown in figure-7. The cotton samples were pretreated with tannic acid before mordanting.

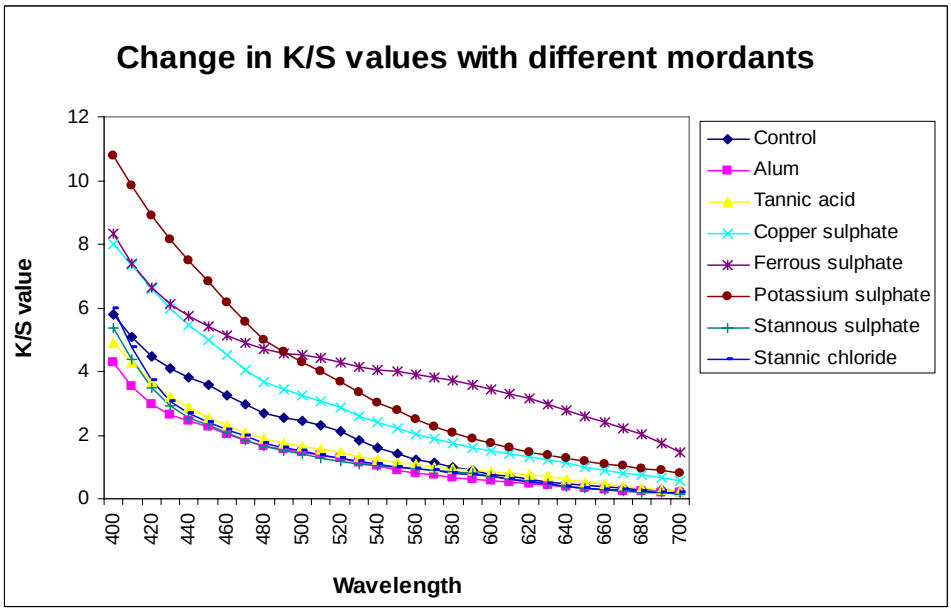

Figure-7 Change in K/S values for Cotton samples

The best values are obtained with ferrous sulphate and the order of reactivity is Fe> Cr > Cu >> Al >Sn (IV) > Sn (II) for silk samples as shown in figure-8.

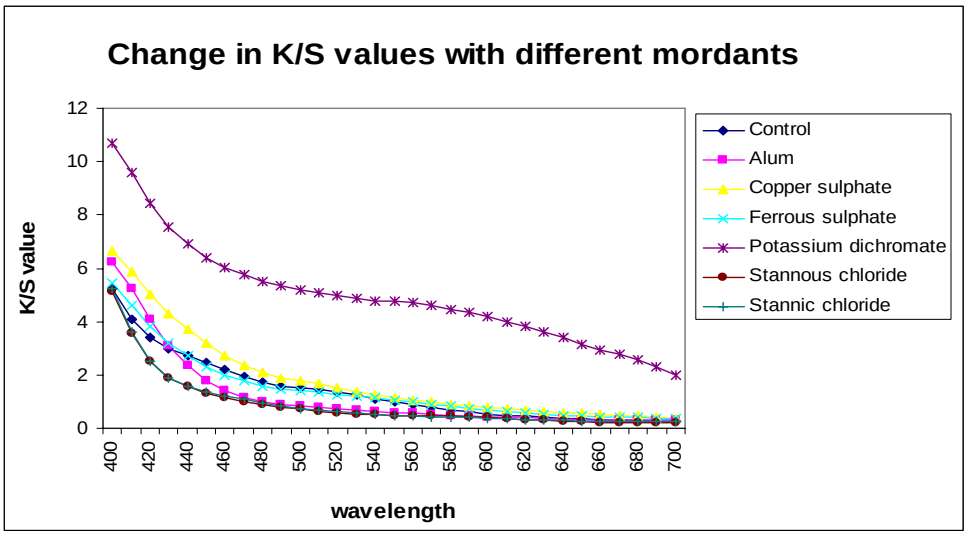

Figure-8-Change in K/S values for Silk samples

The best values are obtained with ferrous sulphate and the order of reactivity is Fe> Cu > Cr >> Al >Sn (IV) > Sn (II) for wool samples as shown in figure-9.

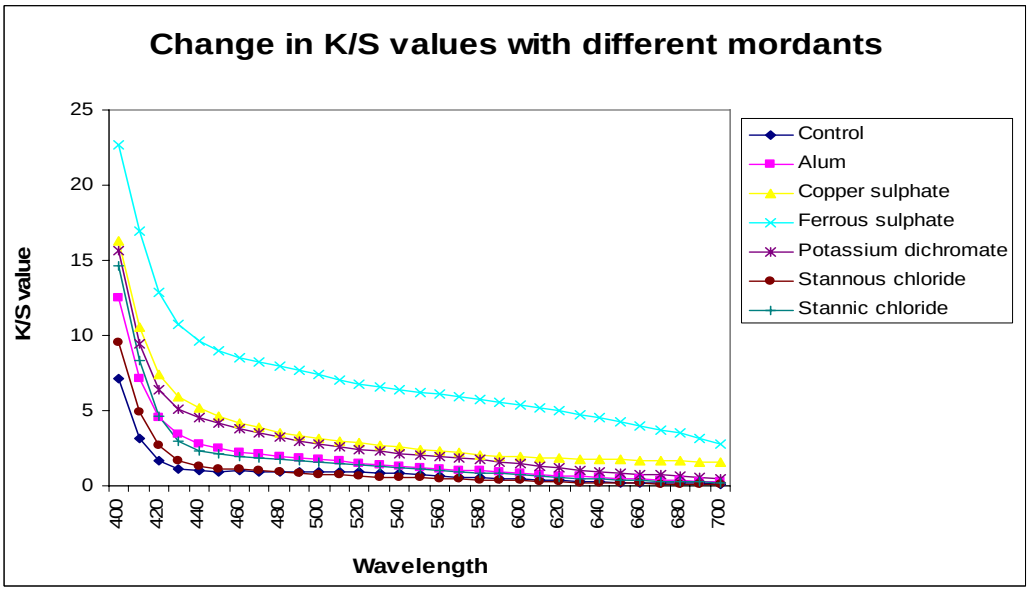

Figure-9-Change in K/S values for Wool samples

4.4. Fastness Properties

It was observed that dyeing with *Garcinia mangostana* gave good fastness properties in conventional dyeing. The Table-I shows L*, a* and b* values and can be seen that mordants which show higher value of L* show lighter shades while lower L* values signifies deeper shades for all the three types of fabric and yarn. The highest K/S for the ferrous sulphate in all the three cases is shown in figure7-9. The CIELab values for cotton, silk and wool samples are shown in tables-I-III. Analysis of the data of table I

reveals that the results of CIELab values and K/S values are consistent. The modest values of L* in the case of Sn(II), Sn(IV) and Al also indicates that the coloristic efficiency or tinctorial value of this natural dye for cotton fabric is not high for these mordants despite the tannic acid pretreatment to cotton fabrics[8].

Table – I -Different pre-mordants, color obtained L*, a*, b*,C, δE and K/S values for dyed cotton fabric with *Garcinia mangostana*

Pre-mordanting	Color obtained	L*	a*	b*	C	δE	K/S
Control		54.817	13.25	24.94	28.24	--	37.61
Alum	Khaki brown	53.338	5.51	20.30	21.04	9.14	29.65
Ferrous sulphate	Greenish brown	49.259	2.60	8.40	8.79	20.43	77.70
Stannous chloride	Camel brown	54.287	7.17	22.47	23.52	6.57	26.05
Copper sulphate	Brown	53.399	7.18	20.98	21.17	7.38	55.98
Potassium dichromate	Brown	54.347	8.62	23.52	25.05	4.85	73.37
Stannic chloride	Almond brown	54.567	8.10	23.21	24.59	5.43	27.19

Table – II -Different pre-mordants, color obtained L*, a*, b*,C, δE and K/S values for dyed Silk fabric with *Garcinia mangostana*

Pre-mordanting	Color obtained	L*	a*	b*	C	δE	K/S
Control		59.974	10.14	24.03	26.09	---	26.31
Alum	Camel brown	62.732	1.02	26.49	26.51	9.84	20.34
Ferrous sulphate	Greenish brown	54.775	1.62	8.48	8.64	18.47	93.32
Stannous chloride	Camel brown	60.860	1.76	23.92	23.96	8.43	15.48
Copper sulphate	Light brown	59.211	6.01	21.04	21.88	5.16	27.19
Potassium dichromate	Almond brown	60.659	5.16	24.87	25.40	5.09	34.52
Stannic chloride	Light brown	61.155	2.37	25.11	25.22	7.93	15.79

Analysis of the data of table II reveals that the results of CIELab values and K/S values for silk dyed fabrics are consistent. The modest values of L* in the case of Sn(II), Sn(IV) and Al also indicates that the coloristic efficiency or tinctorial value of this natural dye for silk fabric is not high for these mordants where as Fe, Cr and Cu are better mordants suited for garicinia extract.

Table – III -Different pre-mordants, color obtained L*, a*, b*,C, δE and K/S values for dyed wool yarn with *Garcinia mangostana*

Pre-mordanting	Color obtained	L*	a*	b*	C	δE	K/S
Control		64.914	10.28	11.87	15.71	--	14.28
Alum	Light brown	67.309	5.20	18.63	19.35	8.79	31.58
Ferrous sulphate	Greenish brown	64.021	1.55	9.64	9.77	9.05	129.57
Stannous chloride	Light brown	68.967	5.73	21.35	22.11	11.27	15.25
Copper sulphate	Khaki green	66.03	1.38	15.45	15.51	9.65	59.47
Potassium dichromate	Camel brown	66.615	4.75	17.57	18.20	8.12	50.51
Stannic chloride	Light brown	67.543	6.59	18.31	19.46	7.87	28.65

Analysis of the data of table III reveals that the results of CIELab values and K/S values for wool dyed yarn are consistent. The modest values of L* in the case of Sn(II), Sn(IV) and Al also indicates that the coloristic efficiency or tinctorial value of this natural dye for wool yarn is not high for these mordants where as Fe, Cr and Cu are better mordants suited for garicinia extract.

Table-IV -Fastness properties for Cotton dyed with *Garcinia mangostana*

Pre-mordanting	Fastness Properties					
	Washing IS-687-79	Light IS-2454-85	Rubbing IS-766-88		Perspiration IS-971-83	
			Dry	Wet	Alkaline	Acidic
Control	3-4	II	3	3	3-4	3
Alum	4/5	IV	4-5	4-5	4/5	4/5
Copper sulphate	4/5	III	3-4	3	4	4
Ferrous sulphate	4/5	IV	3-4	3-4	4	4
Stannous chloride	4/5	III	4	4	4	4
Stannic chloride	4-5	IV	4	4	4	4
Pot. dichromate	4/5	IV	4	4	4	4

Table-V -Fastness properties for Silk dyed with *Garcinia mangostana*

Pre-mordanting	Fastness Properties					
	Washing IS-687-79	Light IS-2454-85	Rubbing IS-766-88		Perspiration IS-971-83	
			Dry	Wet	Alkaline	Acidic
Control	3-4	II	3	3	2-3	2-3
Alum	4/5	IV	4-5	4-5	4/5	4/5
Copper sulphate	4/5	IV	3-4	3	4	4
Ferrous sulphate	4/5	V	3-4	3-4	4	4
Stannous chloride	4/5	III	4	4	4	4
Stannic chloride	4-5	IV	4	4	4	4
Pot. dichromate	4/5	IV	4	4	4	4

Table-VI -Fastness properties for Wool dyed with *Garcinia mangostana*

Pre-mordanting	Fastness Properties					
	Washing IS-687-79	Light IS-2454-85	Rubbing IS-766-88		Perspiration IS-971-83	
			Dry	Wet	Alkaline	Acidic
Control	3	3	3	2-3	2-3	2-3
Alum	4/5	IV	4-5	4-5	4/5	4/5
Copper sulphate	4/5	IV	3-4	3	4	4
Ferrous sulphate	4/5	V	3-4	3-4	4	4
Stannous chloride	4/5	III	4	4	4	4
Stannic chloride	4-5	IV	4	4	4	4
Pot. dichromate	4/5	IV	4	4	4	4

The colorfastness to washing was between 4-5 as shown in the Table-IV-VI for the three different types of dyed samples. Premordanting with metal salts had a higher washing and light fastnesses as compared to the control samples in all the three materials. The improved fastnesses correlate with the higher color depths in the dyed samples. Overall, it could be used for commercial purpose, the dyed samples attain acceptable range. The results clearly show that this aqueous dye is better in terms of better dye uptake, reduced dyeing time and cost

effective as it shows the use of pericarp of the fruit which is a waste.

Conclusion:

This study investigated the feasibility of the natural colorant from the aqueous extract of pericarp of *Garcinia mangostan* prepared by sonication. Use of sonication helped to extract the colorant in just 30 mins instead of the conventional extraction (3hours). Extraction process was modified mainly with an aim that garcinia pericarp(a waste material) can be used as a cheap source of natural dye. The hue color ranged from camel brown to dark chocolate brown. and yielded different shades of brown and khaki brown and khaki greens with good fastness properties. Fe, Cr and Cu mordants are best suited as pre mordants for garcinia extract. The dye has good scope in the commercial dyeing of cotton, silk for garment industry and wool yarn for carpet industry. The knowledge of the chemical structure of the dye molecule helped to understand the role of metal mordant and also minimize the use of the metal mordants as the colorant consists of several prenylated xanthones.

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