Development of printing natural fabrics with curcuma natural dye via nanotechnology

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Abstract:

The present work is undertaken with a view to harness nanotechnology as one of the most important frontier sciences for development of printing natural fabrics using the most eco-friendly dyes, i.e. natural colors. Curcuma natural dye was studied to clarify the impact of nature of nano-size color particles on size, shape, and particle distribution of the natural dye with comparative studies of the K/S and over all fastness properties of printed samples on natural fabrics (wool, silk and cotton). Results showed that the K/S values of nano samples are higher than original samples, irrespective of the nature of the fabric used and /or the concentration of the coloring matter. Alum mordant incorporated with original curcuma can be omitted, and substituted by nano-curcuma without mordant. K/S values of the pre-mordanting acquired the higher values than the simultaneous mordanting irrespective of the fabric used, or dye particles size used, or curcuma concentrations on using tannic acid mordant.

Color fastness to rubbing, and perspiration properties of nano dye is better than the original.

1. *Introduction:*

Natural dyes are as old as textiles themselves [(1)]. They have been used by humans for purposes varying from coloration of food, cosmetics and textiles to imparting other functions to them [(2)].

Curcuma longa L., which known as turmeric was used as a coloring matter and also as medical properties[(3)]. belongs to the Zingiberaceae family, originates from the Indian sub-continent and possibly neighboring areas of Southeast Asia, but it is nowadays widely grown throughout the tropics. Its tuberous rhizomes used as a condiment, a colorant and an aromatic stimulant since antiquity. The pigments in the colorant extracts obtained from Curcuma collectively known as curcuminoids, the major constituent being curcumin, along with small amounts of demethoxycurcumin and bisdemethoxycurcumin Fig (I) [4, 5].

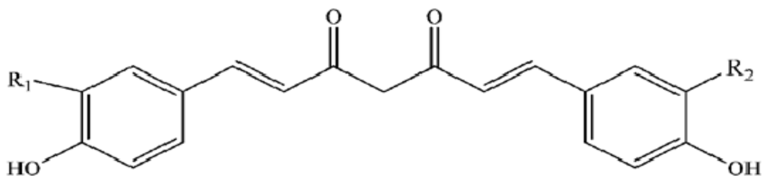

Fig (I): Structure of curcumin and its analogs.

Curcumin and other related curcuminoids are reported to be responsible for yellow color of the dye [6]. Ghoreishian and coworkers dyed silk fabric with turmeric and proved antibacterial properties to silk fabric [7].

The coloring is due to curcuma in which is insoluble in water but soluble in organic solvents such as acetone, ethanol and hexane. A product produced by extracting turmeric with organic solvent and essential oil) from which curcumin (the yellow dye) can be produced by evaporating the essential oil. Turmeric (curcumine) is used as a vegetable dye to give a rich yellow color to silk, cotton and wool. Curcumin has anti-inflammatory, antifungal and antitumorous. It is also widely used as food colorant. It is called C.I Natural Yellow 3, its color index number is C.I, 75300, E100. [8]

Several shortcomings are encountered with conventional natural coloration. Of these are poor wet rubbing fastness, light fastness, poor shades and harsh hand resulting from regular size dye particles and nature of the binder used [9].

To overcome these problems, improving the dispersion of the natural dye becomes necessary. Modification of natural dye morphology can decrease the average of dye particle's diameter to 100-200 nm and, in so doing; the natural dye dispersion acquires greater stability and color strength approaching that of dyes [10].

Nanotechnology is the science and technology of designing, constructing and creating of novel nano-scale structure, 1nm to 100 nm in size, with huger quality, novel performance properties, along with fewer defects compared with those of the bulk material [11].

It can provide high durability to fabrics, because nanoparticles have a large surface area-to-volume ratio and high surface energy, thus presenting better affinity for fabrics and leading to an increase in durability of the function [12].

When matter is reduced in size, it changes its characteristics, such as color and interaction with other matter i.e., chemical activity. The change in characteristics is caused by the change of the electronic properties. By particle size reduction, the surface area of the material is increased. Due to this, a higher percentage of atoms can interact with other matter.

The present work is undertaken with a view to harness nanotechnology as one of the most important frontier sciences for development of printing natural fabrics using the most eco-friendly dyes namely curcuma. This was done to clarify the import of nature of nano-size color particles on size, shape and particles distribution of the natural dyes with comparative studies of the K/S and overall fastness properties. Role of miniaturization of the used curcuma on its printability of cotton, wool and silk in presence and absence of mordants will be investigated.

2. ***Experimental:***

2.1. Materials:

Fabrics:

- Cotton fabric: Mill desized, bleached and mercerized cotton fabrics 165 g / m^2 produced by Misr/Helwan for Spinning and Weaving Company, Helwan, Egypt.
- Wool fabrics: Mill scoured 100% wool fabric supplied by Misr Company. for spinning and weaving (Mehalla El-Kubra) 210 g / m^2 , Mehalla, Egypt.
- Silk fabrics: Mill scoured natural Silk fabric of plain weave 60 g / m^2 supplied by El-Khateib Company. Souhag, Upper Egypt.

Dyestuff: natural Coloring substance turmeric (Curcuma) [which have been purchased from local market] was extracted according to the procedure described latter.

Thickening agents: Commercial synthetic thickening agent, namely Printofix thickener MTB 01 EG liq manufactured by CLARIANT company was also used.

Mordants: Alum [hydrated double sulfate of potassium hydrogen sulfate ($KAl(SO_4)_2.12H_2O$], and tannic Acid ($C_{76}H_{52}O_{46}$).

2.2 Methods:

2.2.1. Extracting of natural coloring matter:

100 g. Curcuma dry powder were added to 1000 ml. water and subjected to boiling under reflux for 30 min. The mixture was left to cool at room temperature and then filtrated off. The filtrated solution was concentrated using a laboratory Rotavapour.

2.2.2. Preparation of nano particles of curcuma natural dye using Ultrasonic stirrer:

Different amount "X" (3, 5, or 7gm) of filtrated solution of Curcuma were suspended in 100ml distilled water under stirring then the solution were set to motion in the Ultrasonic stirrer (The probe is turned to resonate at specific frequency, 20 KHZ $\pm$ 100 HZ). The Ultrasonic stirrer was operated for 60 min at ca 80˚C to reach the nano-size.

2.2.3. Preparation of the printing pastes:

The extracted curcuma color was subjected to minimization using Ultrasonic stirrer as previously mentioned. Different printing pastes containing natural curcuma color before and after minimization were prepared according to the following recipes:

Dye suspension original or nano sample *	20 g
Urea	2.5g
Thickener	2.5g
Binder	5g
Sodium dihydrogen phosphate dehydrate	0.5g
Mordant **	X
Distilled water	Y
Total	100

* 20g was taken from each dyeing solution (original or nano-size) containing curcuma color at a concentration of 3, 5, or 7 g dye in 100 ml water.

** The mordant was incorporated direct in the printing paste.

2.2.4. Mordanting of natural fabrics:

Mordanting of the natural fabrics (cotton, wool or silk) were conducted using two different techniques; either pre-mordanting or simultaneous i.e. added directly to the printing were used.

2.2.5. Printing techniques:

The aforementioned three different fabrics, i.e. wool, cotton, or silk were printed with the prepared printing paste via screen, i.e. screen printing technique.

After printing and dyeing the printed goods were subjected to steaming at 115˚C for 10 minutes for silk, and for 20 minutes for both cotton and wool followed by thoroughly washing and finally air-dried. At the end, the fabrics were assessed for K/S and overall fastness properties.

2.3. Testing, Analysis and measurements:

2.3.1. Transmission electronic microscopy (TEM) [13] :

Particle shape and Size were obtained using aJEOLJEM 1200. Specimens for TEM measurements were prepared by dissolving a drop of colloid solution on a 400 mesh copper grid coated by an amorphous carbon film and evaporating the solvent in air at room temperature. The average diameter of the natural dye nanoparticles was determined from the diameter of 100 nanoparticles found in several arbitrarily chosen areas in enlarged microphotographs.

2.3.2. Color strength & fastness :

The color strength (K/S) of the samples was evaluated by light reflectance technique using Shimadzu UV/Visible spectrophotometer [14]. and the color overall fastness properties: i.e. to washing, perspiration or rubbing fastness were assessed according to standard methods [15].

3. ***Results and Discussion:***

3.1. Dependence of the size of curcuma particles on its concentration:

To start with TEM investigation of the particles size of the curcuma color, Figures 2, 3 and 4 show the TEM micrographs of curcuma at original size, i.e. before subjecting to ultrasonic stirring at a concentration of 3,5 and 7%. Figures 5,6 and 7 represents the particle size after subjecting to ultrasonic stirring for 60 min, at Ca 80 ˚C.

A close examination of figure 2 which represent the TEM at a concentration of a concentration of 3% before subjecting to ultrasonic stirring signifies as average particle size of 223 nm. Indeed this average covers a wide distribution of size particles ranging from 159.4 to 291.7 nm. While figures 5 represents TEM micrograph of the same sample after subjecting to ultrasonic technique.

As is obvious the average of curcuma particle size of 43.7. Indeed this average covers the particle size ranges from 33.2 nm to 68.9 nm. It is further noted that the nanoparticles exhibit a perfectly uniform spherical shape with very broad particle size distribution and with little or no evidence of aggregation / agglomeration.

Figures 3,4 and figures 6.7 represent the TEM before and after miniaturization at concentrations of 5 and 7 % respectively.

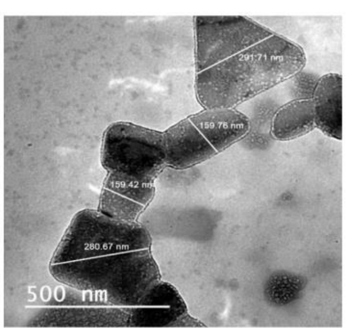

Fig (2) 3% original curcuma

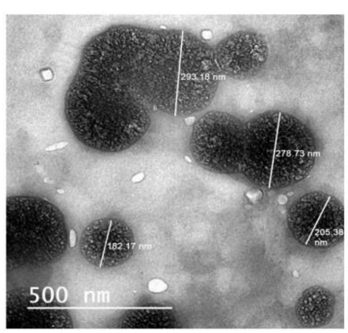

Fig (3) 5% original curcuma

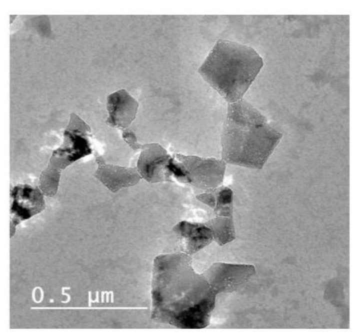

Fig (4) 7% original curcuma

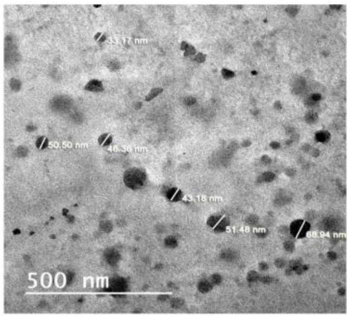

Fig (5) 3% nano curcuma

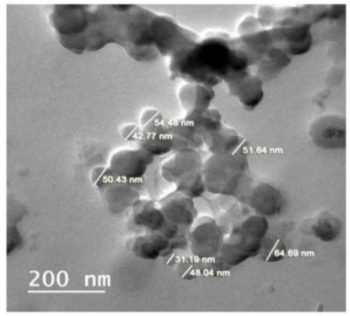

Fig (6) 5% nano curcuma

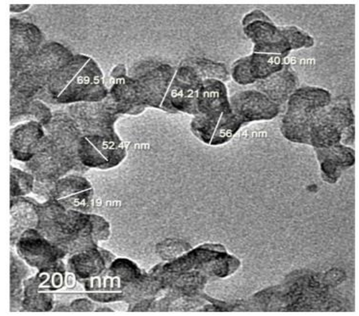

Fig (7) 7% nano curcuma

While table I summarize the effect of concentration of curcuma on the particle size before and after nanofication.

Table I: Comparison between curcuma particle size before and after miniaturization using ultrasound based technique.

Dye	Con. of dye	Original size			Nano size			Percent decrease
		Average size of dye particle	Max. size of dye particle	Min. size of dye particle	Average size of dye particle	Max. size of dye particle	Min. size of dye particle	
Curcuma	3%	222.9	291.7	159.4	43.7	68.9	33.2	80.39%
	5%	239.9	293.2	182.2	49.1	64.7	31.2	79.53%
	7%	261.5	419.5	176.3	56.1	69.5	40.1	78.55%

It is clear from the micrographs that the size, shape and particle size distribution of nano-dye rely on dye concentration. It was found that at lower concentration, the nanoparticles exhibit a perfectly uniform spherical shape with broad particle size distribution and with little or no evidence of aggregation / agglomeration.

The above finding and those connected with changes in shape and particle size distribution could be explained in terms of disintegration of the dye to much smaller size of large surface areas, which favor the possibility of aggregation and agglomeration.

It is clear from the data that, by increasing the concentration of the curcuma dye from 3-7%, the average size of the nano-dye particle increased, in both original size and nano-size.

The decrease percentage of miniaturization of particle size are (80.39 %, 79.53%, 78.55%) at dye concentrations of (3, 5, and 7%) respectively. This reflects the higher effectiveness of ultrasonic stirrer in severely breaking down the dye particles through the growth of cavitation.

3.2. Effect of miniaturization of curcuma color to nano-sized on its printability on natural fabrics:

To investigate the effect of decreasing the particle size of curcuma to the nano-form on its printability on natural fabrics, printing pastes containing the aforementioned three concentrations before and after miniaturization were prepared in presence or absence of mordants. The prepared pastes were applied to print the aforementioned three natural fabrics according to the procedure described in the experimental section. Given below the results obtained along with the appropriate discussion.

3.2.1. Comparison between original and nano-size: (In absence of mordant)

Table II represents the data of K/S obtained using different concentrations of curcuma before and after militarization

Table II: Effect of miniaturization of curcuma color to nano-sized on K/S in absence of mordant.

Fabric	Dye Con. %	K/S Without mordant		
		In original form	In nano Form	% increase in K/S
On Wool	3	1.49	2.47	65.8%
	5	2.18	2.72	24.8%
	7	2.24	2.75	22.8%
On Silk	3	1.31	2.53	93.1%
	5	2.06	2.73	32.5%
	7	2.17	2.21	1.8%
On Cotton	3	0.51	1.73	239.2%
	5	1.50	3.34	122.7%
	7	1.48	1.81	22.3%

It is clear from the data of Table II that the K/S is oppositely related to the size of the nano particles. Decreasing the particle size is accompanied by substantial enhancement in color strength.

The increase in K/S on decreasing the particle size to the nano-scale may be due to the virtue of their small nano-scale size and large surface area which make the particle defuse faster in the interior of the printed fabrics and distributed themselves on the fabric surface during printing. In so doing, they produce prints with strong color shade and, therefore, higher color strength compared with the original particles which acquire relatively larger size.

It is clear from the data, Irrespective of the fabric used, the K/S values of nano samples are higher than original samples.

Proteinic fabrics i.e. wool and silk acquire high affinity for natural colors than cellulosic fiber i.e. cotton. It has been reported (16, 17) that natural dyes are high molecular weight compounds containing phenolic hydroxyl groups which enable them to form effective cross-links between proteins such as wool and silk, where they form three types of bonds namely. (a) Hydrogen bond: which is formed between phenolic hydroxyl groups of natural dye and the free amino and amides groups of the proteins. (b) Ionic bond: it is formed between suitable charged anionic groups of the natural dye and cationic groups on the protein. (c) Covalent bond: it is formed by interaction of any quinone or semi quinone group present in natural dye with any suitable reactive groups in the protein.

However in case of cellulosic, exemplified by cotton, the natural dye could form only two types of bonds as follows: (a) Hydrogen bond: which is formed between phenolic hydroxyl groups of natural dye and the hydroxyl groups of cellulose. (b) Covalent bond which may be formed by the interaction of quinone or semi quinone groups present in natural dye with suitable functional groups in the cellulose.

In addition, as the concentration of the curcuma dye increases, the K/S value increases irrespective of the particle size.

3.2.2. Comparison between original and nano-size of curcuma dye in presence of pre-mordant:

Irrespective of the fabric used; the K/S values of nano samples are higher than original samples This phenomenon holds true in order to a matter is reduced in size, it changes its characteristics, such as color and interaction with other matter.

3.2.3. Comparison between nano-dye and original dye with mordant:

To investigate the possibility of using nano-dye instead of using mordants with original dye. Different samples (wool, silk or cotton) were printed with different mordants (alum or tannic acid) incorporated with original curcuma dye, while other samples printed with only nano-curcuma dye for comparison.

Table (III): comparison between printing dye in nano-form, and dye in original form incorporate with mordant.

Nature of fabric	Dye conc. %	K/S of Nano dye	K/S of original dye incorporate with mordant	
			Alum	Tannic acid
Wool	3%	1.49	1.32	2.09
	5%	2.18	1.71	2.39
	7%	2.24	2.40	2.28
Silk	3%	2.53	1.20	2.27
	5%	2.73	1.45	2.71
	7%	2.21	1.94	3.17
Cotton	3%	1.73	0.62	1.43
	5%	3.34	0.95	2.15
	7%	1.81	1.66	2.23

It is clear from the data of table III that; the K/S values of nano- dye samples are higher than the original dye incorporate with alum mordant when applied at cotton or silk fabric. Therefore, alum mordant incorporate with original curcuma can be substituted by nano-curcuma without mordant.

3.2.4. Comparison between original-dye, nano-dye, and nano-dye incorporated with nano-tannic acid at dye concentration 5%:

It is clear from figure (8) that, the dye in nano form acquired the highest K/S values compared with original-dye, and incorporate dye and tannic acid in the nano form at dye concentration 5%.

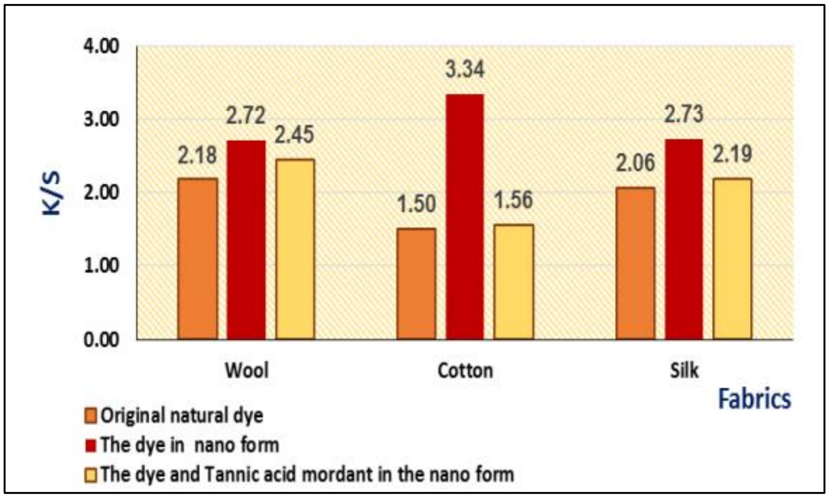

Fig (8): Comparison between K/S of curcuma dye in original and nano- size and nano-dye incorporate with nano-tannic acid

3.2.5. Effect of mordanting technique on K/S of printing curcuma colorant in original form:

To study techniques of mordanting (pre-mordanting and simultaneous mordanting) of Alum/Tannic acid mordants and their effects on printing curcuma in original form, on wool, silk or cotton samples, and compared with non-mordanted samples, The K/S values were remarked as shown in Table (IV).

On using Alum mordant :The highest K/S values was obtained on using 7% of curcuma dye, irrespective of the fabric used or the applied technique.

On using Tannic mordant: the K/S of pre-mordant samples is higher than the simultaneous samples irrespective of fabric used.

Table(IV): Comparison between using pre-mordanting and simultaneous mordanting on K/S of printed original-form.

Nature of fabric	Dye conc. %	K/S of samples without mordant	K/S of samples with Alum mordant		K/S of samples with Tannic Acid mordant	
			I	II	I	II
Wool	3%	1.49	1.63	1.32	2.32	2.09
	5%	2.18	2.46	1.71	3.45	2.39
	7%	2.24	2.78	2.40	3.29	2.28
Silk	3%	1.31	1.11	1.20	5.16	2.27
	5%	2.06	1.92	1.45	6.89	2.71
	7%	2.17	1.95	1.94	5.54	3.17
Cotton	3%	0.51	0.47	0.62	1.31	1.43
	5%	1.50	1.48	0.95	2.18	2.15
	7%	1.48	1.58	1.66	2.81	2.23

(I): K/S of the mordant was applied via padding technique.

(II): K/S of the mordant was incorporated direct in the printing paste.

3.2.6. Comparison between using pre-mordanting and simultaneous mordanting on K/S of printed nano-form:

Table (V): Comparison between using pre-mordanting and simultaneous mordanting on K/S of printed nano-form.

Nature of fabric	Dye conc. %	K/S of samples without mordant	K/S of samples with Alum mordant		K/S of samples with Tannic Acid mordant	
			I	II	I	II
Wool	3%	2.47	3.54	2.06	3.83	2.53
	5%	2.72	3.45	2.56	3.91	3.29
	7%	2.75	3.26	2.25	3.85	2.73
Silk	3%	2.53	1.95	1.80	6.82	2.47
	5%	2.73	2.46	2.55	7.39	3.75
	7%	2.21	2.00	2.03	6.41	3.06
Cotton	3%	1.73	1.37	1.17	2.53	1.61
	5%	3.34	3.20	1.96	3.43	3.02
	7%	1.81	2.12	1.63	3.00	2.24

(I): K/S of the mordant was applied via padding technique.

(II): K/S of the mordant was incorporated direct in the printing paste.

It's clear from the data of Table (V) On using Alum mordant: K/S values of the pre-mordanting acquired the higher values than the simultaneous mordanting on wool and cotton fabrics.

On using tannic acid mordant: K/S values of the pre-mordanting acquired the higher values than the simultaneous mordanting irrespective of the fabric used or curcuma concentrations.

3.2.7. Effect of miniaturization on fastness properties of curcuma printed samples:

The color fastness properties of the natural fabrics printed with curcuma in presences of different mordants (Alum or Tannic acid) or without mordant were measured. Table (VI) represents the data for the K/S values and the color fastness to washing, to rubbing, and to perspiration for deferent fabrics (Wool-Silk-Cotton) printed with curcuma before and after miniaturization.

Table (VI): color strength (K/S) and overall fastness properties of wool, silk and cotton printed with curcuma before and after miniaturization.

On wool

a) Before miniaturization

Samples before miniaturization				Washing fastness		Rubbing fastness		Perspiration			
								Acidic		Alkaline	
Printed fabric	Mordant	Dye conc. gm / 100 ml H_2O	K/S of Printed fabric	Alt.	St.	Dry	Wet	Alt.	St.	Alt.	St.
Wool	Without mordant	3	1.49	4-5	4	4-5	4-5	3	2-3	3	3
		5	2.18	4-5	4	4	4	3	2-3	3-4	3
		7	2.24	4-5	4	4	4	3	3	3-4	3-4
	With Alum	3	1.63	4-5	4-5	4	4	3-4	3-4	3-4	3-4
		5	2.46	4-5	4-5	4	3-4	3-4	3	4	3-4
		7	2.78	4-5	4	4	3-4	3-4	3	4	4
	With Tannic acid	3	2.01	4-5	4	4-5	4-5	3-4	3	3-4	3
		5	2.32	4-5	4	4-5	4	2-3	2-3	3	2-3
		7	3.45	4-5	4	4-5	3-4	3	2-3	3-4	3

Alt. : Alteration St.: Staining

b) After miniaturization

Samples After miniaturization				Washing fastness		Rubbing fastness		Perspiration			
								Acidic		Alkaline	
Printed fabric	Mordant	Dye conc. gm / 100 ml H_2O	K/S of Printed fabric	Alt.	St.	Dry	Wet	Alt.	St.	Alt.	St.
Wool	Without mordant	3	2.47	4-5	4	4	4	3-4	3	3-4	3-4
		5	2.72	4-5	4	4-5	4-5	3-4	3-4	3-4	3-4
		7	2.75	4-5	4	4-5	4	3-4	3	3-4	3-4
	With Alum	3	3.54	4-5	4-5	4	3-4	4	3-4	4	4
		5	3.45	4-5	4-5	4	3	4	3-4	4-5	4
		7	3.26	4-5	4	4	3-4	4	4	4-5	4
	With Tannic acid	3	3.83	4-5	4	4-5	3-4	3-4	3-4	3-4	3
		5	3.91	4-5	4	4-5	3-4	3-4	3-4	3-4	3
		7	3.85	4-5	4	4	4	3-4	3-4	3-4	3

On Silk

a) Before miniaturization

Samples before miniaturization				Washing fastness		Rubbing fastness		Perspiration			
								Acidic		Alkaline	
Printed fabric	Mordant	Dye conc. gm / 100 ml H_2O	K/S of Printed fabric	Alt.	St.	Dry	Wet	Alt.	St.	Alt.	St.
Silk	Without mordant	3	1.31	4-5	4	4-5	4-5	4	4	3	3
		5	2.06	4-5	4	4-5	4	4	3-4	3	3
		7	2.17	4-5	4	4-5	3-4	4	3-4	3	3
	With Alum	3	1.11	4-5	4-5	4	4	4	4	4	3-4
		5	1.92	4-5	4-5	4	4	4	3-4	4	3-4
		7	1.95	4-5	4	4	4	4	4	4	4
	With Tannic acid	3	5.16	4-5	4	4	4	3-4	3-4	3-4	3
		5	6.89	4-5	4	4	2-3	4	3-4	3-4	3
		7	5.54	4-5	3-4	4	3	4	3-4	3-4	3

Alt. : Alteration St.: Staining

b) After miniaturization

Samples After miniaturization				Washing fastness		Rubbing fastness		Perspiration			
								Acidic		Alkaline	
Printed fabric	Mordant	Dye conc. gm / 100 ml H_2O	K/S of Printed fabric	Alt.	St.	Dry	Wet	Alt.	St.	Alt.	St.
Silk	Without mordant	3	2.53	4-5	4	4-5	3-4	4	3-4	3-4	3
		5	2,73	4-5	4	4-5	3	4	4	3-4	3-4
		7	2.21	4-5	4	4	3-4	4-5	4-5	3-4	3-4
	With Alum	3	1.95	4-5	4-5	4-5	4	4-5	4	4-5	4
		5	2.46	4-5	4-5	4	4	4-5	4-5	4-5	4-5
		7	2.00	4-5	4-5	4-5	4	4-5	4-5	4-5	4-5
	With Tannic acid	3	6.82	4-5	4	4	3-4	4	3-4	3-4	3-4
		5	7.93	4-5	4	4	2-3	4	3-4	3-4	3-4
		7	6.41	4-5	4	3-4	2-3	4	4	3-4	3-4

Alt. : Alteration St.: Staining

On cotton

a) Before miniaturization

Samples before miniaturization				Washing fastness		Rubbing fastness		Perspiration			
								Acidic		Alkaline	
Printed fabric	Mordant	Dye conc. gm / 100 ml H_2O	K/S of Printed fabric	Alt.	St.	Dry	Wet	Alt.	St.	Alt.	St.
Cotton	Without mordant	3	0.51	4-5	4	4-5	4	3-4	3-4	3-4	3-4
		5	1.50	4-5	4	4-5	3	3-4	3-4	3-4	3-4
		7	1.48	4-5	4	4-5	3	3-4	3	3-4	3-4
	With Alum	3	0.47	4-5	4-5	4-5	4-5	4	4	4	4
		5	1.48	4-5	4-5	4-5	4	4	4	4	4
		7	1.58	4-5	4-5	4-5	4	4	3-4	4	3-4
	With Tannic acid	3	1.31	4-5	4-5	4-5	4-5	3-4	3-4	3-4	3
		5	2.18	4-5	4	4-5	4	3-4	3-4	3-4	3
		7	2.81	4-5	4	4-5	4	3-4	3-4	3-4	3-4

Alt. : Alteration St.: Staining

b) After miniaturization

Samples After miniaturization				Washing fastness		Rubbing fastness		Perspiration			
								Acidic		Alkaline	
Printed fabric	Mordant	Dye conc. gm / 100 ml H_2O	K/S of Printed fabric	Alt.	St.	Dry	Wet	Alt.	St.	Alt.	St.
Cotton	Without mordant	3	1.73	4-5	4	4-5	3-4	4	4	4	3-4
		5	3.34	4-5	4	4-5	3-4	4	4	4	3-4
		7	1.81	4-5	4-5	4-5	3-4	4	4	4	4
	With Alum	3	1.37	4-5	4-5	4-5	4	4-5	4	4	3-4
		5	3.20	4-5	4-5	4-5	4-5	4-5	4	4-5	4
		7	2.12	4-5	4-5	4-5	4	4-5	4-5	4-5	4-5
	With Tannic acid	3	2.53	4-5	4-5	4-5	4	4	4	3-4	3-4
		5	3.43	4-5	4-5	4-5	3-4	4	4	3-4	3-4
		7	3.00	4-5	4-5	4-5	4	4-5	4-5	4	3-4

Alt. : Alteration St.: Staining

The first glance at the result of table (VI) would imply that the color strength (K/S) for the printed samples before the miniaturization is much lower than after miniaturization.

Printability of the nano-dye particles would be governed by several factors of which nature of the substrate to be printed comes to play an important role. For example On wool fabric: before miniaturization: the data shows that washing and rubbing properties ranging from very good to excellent whereas the perspiration range from good to very good. While after the miniaturization: the overall properties ranging from very good to excellent.

With respect to fastness properties, there is a tendency of improvement of the perspiration fastness while keeping the washing and rubbing fastness unaltered after miniaturization of the curcuma dye.

4. Conclusions:

- Nanoscale curcuma natural dye with particle size less than 100 nm were successfully prepared by using ultrasonic starrier.
- Increasing the dye concentration from 3 to 7gm/ 100ml water increases the average of dye particle size from 43.7 nm to 56.1nm with greater tendency of the nanoparticles to aggregate / agglomerate when higher dye concentrations were used.
- In absence of mordant, proteinic fabrics i.e. wool and silk acquire high affinity for natural colors than cellulosic fiber i.e. cotton.
- Irrespective of the fabric used, the K/S values of nano samples are higher than original samples.
- Alum mordant incorporate with original curcuma can be substituted by nano-curcuma.
- The nano curcuma acquired the highest K/S values compared with original curcuma, and nano-curcuma incorporated with nano-tannic acid at dye concentration 5%.
- K/S values of the pre-mordanting acquired the higher values than the simultaneous mordanting irrespective of the fabric used or dye particles size used or curcuma concentrations on using tannic acid mordant.
- Rubbing and perspiration fastness properties of nano-dye is better than original dye.

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