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Effect of acid dyes on colour fastness properties of silk fabric

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Abstract
Silk- the natural fiber has been an inseparable part of Indian culture and tradition over thousands of years. Silk has always been the symbol of royalty and universally accepted as "the queen of textiles" due to its lustrous appearance and peach like softness. The colouration of this royal fibre is also an art form. In this study, the degummed mulberry silk fabrics were dyed with four different colours of acid dyes *viz.*, orange, red, blue and black hues. These dyes fabrics were subjected to physical and colour fastness properties. The dyed silk fabrics exhibited good colour fastness property and total colour difference. The mechanical properties *viz.*, cloth count, cloth thickness and cloth weight of dyed silk fabrics were improved and concluded that the acid dyes are efficient for dyeing silk fabric which is evident from their excellent fixation, binding stability and fastness properties.

Keywords: Mulberry silk, acid dyes, colour fastness property, gray scale, mechanical properties

1. Introduction

Silk is a naturally occurring protein fibre produced by the silk worms and has been potentially used as a textile material. Natural raw silk is composed mainly of sericin about (22.25%), fibroin about (62.5-67.0%) and the rest is of water and mineral salts. Fibroin is a single protein which is insoluble in hot water. On the other hand, sericin is primarily amorphous and acts as a gum binder to maintain the structural integrity of the cocoon, which makes it more water soluble than fibroin (Swapna *et al.* 2014) [4]. This fine filament fibre is well known for its sheen texture, water absorbency, dyeing affinity, thermal tolerances along with insulation property (Shaikh *et al.* 2016). All over the world, Silk is considered as anti allergic, eco-friendly, and symbol of beauty & thus famous as 'Queen of Textile fibre'.

The silk can be dyed with anionic dye such as acid, metal complexes, reactive and selected direct dyes because it has slightly cationic character with isoelectric point of pH 5.0. But the main objective of colouration of a textile fibre is that the permanency of the colour and should not allow damage of natural abstract of fibre. This implies that it should not destroy its colour during processing *i.e.*, washing, light, rubbing and perspiration. So whatever dyestuff we use for silk dyeing it is very essential to have sustainability of that dyestuff.

Acid dyes are a large class of dyes which comprises various categories. Most important acid dyes are sulfonic acid derivatives of azoic dyes. The practical uses of these dyes are characterized by their capacity to dye protein and polyamide fibers. Acid dyes are water soluble, bright in colors and have reasonably good washing fastness properties. They contain a chromophoric group and an acidic group, usually – SO_3H, in the form of sodium salt that impart water solubility (Zeeshan *et al.* 2018) [5] and give the dye molecules a negative charge. In an acidic solution, the -NH_2 functionalities of the fibres are protonated to give a positive charge: -NH_3+. This charge interacts with the negative dye charge, allowing the formation of ionic interactions. As the acid dyes are effective on protein fibres like silk, hence the present study is developed with an objective, to evaluate the colour fastness properties of dyed silk fabrics with acid dyes of varied hues.

2. Material and Methods

2.1 Selection of fabric sample

For this investigation, the mulberry silk fabric was selected and collected from local market of Dharwad. The silk fabric was scoured and degummed for further dyeing process.

2.2 Selection of dye colours

Four different colours of acid dyes *viz.*, orange, red, blue and black were selected for the dyeing of silk fabric.

2.3 Dyeing process
The silk fabric was scoured and degummed prior to dyeing. The scoured and degummed silk fabrics were dyed in each hue of acid dyes separately with the following procedure.

2.3.1 Procedure
The varied acid dye stuffs were pasted by adding desirable amount of water. The pastes were dissolved by adding slowly warm water and the solutions were made to required level (MLR - 1:30) and made slightly acidic pH using acetic acid. The silk material were entered at 40^{o}C the temperature of the baths raised gradually to 80^{o}C and the baths were maintained at this temperature for nearly one hour until the dyeing is completed. After dyeing, the silk samples were rinsed in a dilute solution of acetic acid, squeezed well and shade dried.

Recipe

MLR	1:30
Dye	2% owm
Acetic acid	1% owm
Temperature	80^{o}C
Duration	60 min

2.4 Assessment of physical properties of dyed silk fabrics
The dyed silk fabrics were subjected to test physical properties *viz.,* Cloth count, Cloth thickness and Cloth weight using standard test procedures viz., BS method 2862: 1957, ASTM test method D: 1777-1975 and IS 1964:2001 respectively.

2.5 Colourfastness test
Colour is the most important component of the fabric and garment, one of the means to make the fabrics and garments more attractive, appealing and promote in adding colour to them, the consumers accept retention of the original hue during wear and tear. Colour strength is the coloured property of the surface of a textile and does not include the dyeing status of the interior. Colour fastness is the resistance of a material to change in any of its colour characteristics, to the transfer of its colourants to adjacent materials or both.

2.5.1 Colourfastness to sunlight
Fastness to sunlight of the specimen was tested as per the IS test method: 786-1985. A specimen of 1 X 6 cm is wound closely on a card and was mounted in the exposure rack. The rack was placed at an angle of 45^o. The rack was exposed everyday from 9 am to 3 pm (6hrs/day) for 8 days. The dyed and exposed samples were evaluated using colour spectrophotometer after 48 hrs of exposure.

2.5.2 Colour strength measurement
Colour strength (K/S) values of the samples were measured by using Minolta colour spectrophotometer. Five readings were recorded for each samples and an average value was calculated. Where, K is the absorption coefficient and S is the scattering coefficient. Higher the K/S values, greater the colour yield.

2.5.3 Colour coordinates (CIE L* a* b*) and Total colour difference (ΔE)
Colour space in which value L* a* and b* are plotted at right angles to one another to form a three dimensional coordinate system. Equal distance in the space approximately represents equal colour differences. Value L* represents lightness / darkness, value a* represents the redness/greenness while b* is indicative of yellowness or blueness of the samples.
To study the colour change of dyed samples in comparison to the control, the reflectance spectrum of the dyed samples were measured by colour spectrophotometer.

2.5.4 Evaluation of colour fastness properties through Gray scale
Colourfastness properties of all the samples were also evaluated using gray scale. Original sample and tested specimen were placed side by side in the same plane and oriented in the same direction along with the respective grey scale. The visual difference between original tested specimens in the presence of sunlight at an angle of 45^o was compared by viewing perpendicular to the plane of the surfaces with the respective grey scale and colour fastness rating was recorded.

Grey scale ratings

Sources for Colour Change (CC)	Ratings
Very poor	1
Poor	2
Fair	3
Good	4
Excellent	5

3. Results and Discussion
3.1 Dyeing of silk with acid dye
The acid dyestuff is the first place of the original members of the class were applied in a bath containing mineral or organic acid and secondly because they were nearly all sodium salts of organic acid and the anion is active coloured component. Acid dyes are usually sodium salts of sulphonic acids, of less frequently of carboxylic acids and are therefore anionic in aqueous solution. They will dye fibres with cationic sites. These are usually substituted ammonium ion such as wool, silk and nylon. These fibres absorb acids. The acid protonates the fibre's amino groups and they become cationic. Dyeing involves exchange of the anion associated with an ammonium ion in the fibre with a dye in the bath.

Reaction of silk fibre with acid dye

$$\text{Fibre–NH}_2\text{(S)} + \text{H}^+\text{(aq)} + \text{HSO}_4\text{(aq)} \longrightarrow \text{Fibre–NH}_3^+\ \text{HSO}_4^-\text{(S)}$$

$$\text{Fibre–NH}_3^+\ \text{HSO}_4^-\text{(S)} + \text{Dye-SO}_3\text{(aq)} \longrightarrow \text{Fibre–NH}_3^+\ \text{Dye-SO}_3^-\text{(S)} + \text{HSO}_4^-\text{(aq)}$$

Fig 1: Reaction of silk fibre with acid dyes

3.2 Physical properties of dyed silk fabrics with acid dyes
In textiles, the cloth count, cloth thickness and cloth weight are the basic physical properties of fabrics where, cloth count is the number of ends and picks per inch unit area, cloth thickness is the distance between the upper and lower surface of the material measured (mm) under a specific pressure and the cloth weight is articulated either as grams per square meter or as grams per linear meter.
A perusal of Table 1 revealed that, the cloth count of all the silk fabric samples has increased after dyeing when compared with control samples. The warp way cloth count attained highest value of all the silk samples compared to weft way cloth count value. Irrespective of dyed silk samples, the black attained highest warp way (126) and weft way (108) cloth count followed by blue (warp:126, weft:106), red (warp:124, weft:104) and orange (warp:122, weft:104) dyed silk fabrics

respectively.
The cloth thickness of all the dyed silk fabrics found to be greater than control sample. Among the dyed samples, the Black attained higher values of thickness (0.16mm) followed by Blue (0.15 mm), red (0.14 mm) and orange (0.14 mm) dyed silk fabrics.
Cloth weight of all the dyed silk samples was increased in dyed silk samples compared to control samples. After dyeing of silk fabrics with varied colours, the black dyed silk fabric showed higher values of cloth weight (60.40) followed by Blue (56.80), red (53.60) and orange (52.80) dyed silk fabrics respectively.
The cloth count, cloth thickness and cloth weight of all the dyed silk fabrics were increased compared to control samples. This may be due to entrapment and fixation of dye molecules within fibre molecule structure and also consolidation of ends and picks during dyeing process. The same results were found by Savitri (2016) [2] in her study on Effect of reactive dyes on silk fabrics.

Table 1: Physical properties of dyed silk fabrics with acid dyes

Sl. No.	Silk fabrics	Cloth count (Ne)		Thickness (mm)	Cloth weight (GSM)		
		Warp	Weft		Percent Warp	Percent Weft	Cloth weight
1.	Control	120	102	0.12	25.60	20.00	45.60
2.	Orange	122	104	0.14	30.40	22.40	52.80
3.	Red	124	104	0.14	30.80	22.80	53.60
4.	Blue	126	106	0.15	32.80	24.40	56.80
5.	Black	126	108	0.16	34.30	26.20	60.40

3.3 Effect of sunlight fastness on colour strength of silk fabrics dyed with acid dyes

Surface depth of the colour, K/S value of the dyed silk samples was determined using colour spectrophotometer & it is revealed that the colour strength (K/S) of all the dyed samples were decreased compared to control samples after exposing to sunlight (Table 2).
Among all the dyed samples, higher values of colour strength was seen in black dyed sample (91.90) followed by blue (75.95), red (75.31) and orange (74.32) dyed samples. The higher reflectance value depicted in black *i.e.*, 15.14 followed by blue (14.26), red (12.35) and orange (10.49) dyed samples. The dyed samples showed the increased colour strength values with decreased reflectance values.
Silk fabric dyed with dark hue *i.e.*, Black and blue showed better K/S and reflectance value after subjecting to sunlight test followed by red and orange dyed samples which showed lighter hue. It may also be due to the stable arrangement of electrons which is resistant to photo degradation by the UV rays stated by Gohl and Vilensky (1987).
All the dyed samples depicted lower values of colour strength and reflectance compared to standard sample due to the absorption of ultraviolet rays with higher energy raises the dye molecules to an electronically excited state and initiate the degradation of the dye due to photo-oxidation. The level of degradation goes on varies for each dye molecules due to their constitution and structure.

Tables 2: Effect of sunlight fastness on colour strength of silk fabrics dyed with acid dyes

Sl. No.	Dyed Silk fabrics with different colours of acid dye	Variables	K/S	Reflectance
1.	Orange	Standard	134.55	16.62
		Sample	74.32	12.35
2.	Red	Standard	131.65	13.81
		Sample	75.95	10.49
3.	Blue	Standard	132.78	20.10
		Sample	75.31	15.14
4.	Black	Standard	108.81	15.51
		Sample	91.90	14.26

3.4 Effect of sunlight fastness on colour coordinates and total colour difference of silk fabrics dyed with acid dyes

All the dyed silk fabrics showed decreased in colour coordinates i.e., L, a, b values after exposing to sunlight than control samples. It means that the dyed silk fabrics become lighter in colour than control samples. The decreased in L* value observed in orange (59.70) followed by red (45.76), Blue (22.92) and Black (22.45) dyed samples compared to control samples respectively. The same trend was found in a* values *i.e.*, orange (50.47) followed by red (54.90), Blue (12.30) and Black (10.34) dyed samples compared to control samples respectively. In general the b* values of dyed silk samples also decreased *i.e.*, orange (60.29) followed by red (26.76), Blue (17.72) and Black (12.72) dyed samples compared to control samples respectively. Among all the samples, the red (4.03) depicted greater values of total colour difference followed by orange (3.71), blue (2.57) and black (1.08) respectively (Table 3).

Table 3: Effect of sunlight fastness on colour coordinates and total colour difference of silk fabrics dyed with acid dyes

Sl. No.	Dyed Silk fabrics with different colours of acid dye	Variables	L*	a*	b*	dE
1.	Orange	Standard	59.70	50.77	63.41	3.71
		Sample	57.71	50.47	60.29	
2.	Red	Standard	47.88	57.10	29.44	4.03
		Sample	45.76	54.90	26.76	
3.	Blue	Standard	22.95	13.79	36.49	2.57
		Sample	22.92	12.30	17.72	

4.	Black	Standard	21.47	10.37	12.78	1.08
		Sample	22.35	10.34	12.72	

3.5 Effect of sunlight on colour fastness (ratings) of dyed silk fabrics with acid dyes

The effect of sun light on colourfastness of dyed silk fabrics with acid dyes presented in the Table 4. All the dyed silk fabrics with varied colours of acid dyes *viz.*, orange, red, blue and black showed good to excellent (4, 4/5) ratings after exposure to sunlight compared to control sample. Among the dyed silk fabrics, orange and red silk fabrics faded more colour as compared to other dyed silk fabrics. The fading may be due to with short wavelength with high energy leads to breakdown in the light energy absorption capacity of the electrons of the chromophores or a breakdown in the structure of the dye molecules. when sunlight energy is absorbed, the loosely held electrons of the chromophores are raised to higher level *i.e.,* that become more active.

Table 4: Effect of sunlight on colour fastness (ratings) of dyed silk fabrics with acid dyes

Dyed Silk fabrics with different colours of acid dye	Variables	Colour fastness ratings
Orange	Standard	4/5
	Sample	4
Red	Standard	4/5
	Sample	4
Blue	Standard	4/5
	Sample	4/5
Black	Standard	4/5
	Sample	4/5

4. Conclusion

In a nutshell of the silk fabrics dyed with acid dyes of varied colours *viz.,* orange, red, blue and black hue showed good colour fastness property and total colour difference. The dyed silk fabrics improved mechanical properties *viz.,* cloth count, cloth thickness and cloth weight. The versatility of the varied shades of acid dyes can meet the requirement of the textile designers, industries, fashion era and consumers and also it proved beneficial in day to day use of silk fabric.

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