Chemical Science International Journal

Volume 33, Issue 3, Page 109-118, 2024; Article no.CSIJ.116866
ISSN: 2456-706X
(Past name: American Chemical Science Journal, Past ISSN: 2249-0205)

Comparative Study on Dyeing Behaviours of Tasar and Tasar Blended Silk Fabrics

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/CSJI/2024/v33i3898

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/116866

Original Research Article

Received: 10/03/2024
Accepted: 11/05/2024
Published: 13/05/2024

ABSTRACT

Tasar silk is widely sought after because to its natural beauty, durability, sustainability, and cultural relevance. Despite the long-standing yearning for Tasar textiles in their natural colour, weavers can only manufacture a limited number of different designs and types of the silk.It has become necessary to dye the Tasar fabric a different colour since the younger generation requires 100% Tasar cloths in a range of styles and colour combinations.Some manufacturers are now dyeing Tasar fabrics in smaller quantities, but their processing quality is subpar due to non-compliance with correct procedures for color concentration, time intervals, and warm washing, resulting in uneven dyeing, inconsistent hues, and poor fastness attributes.However, considering the current circumstances, it is essential that the Tasar Silk Industry understands how both pure Tasar fabrics and Tasar-blended fabrics are endowed with the fastness properties of Lanaset, Acid, and Reactive dyes.In this article, a comperative study was carried out to understand the dyeing behaviour of Acid, Lanaset and Reactive dye on Tasar x Tasar fabrics and Tasar x Mulberry fabrics. The fabric

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Cite as: *Ghosh, R. R., Radhalakshmi, Y., & Periyasamy, S. (2024). Comparative Study on Dyeing Behaviours of Tasar and Tasar Blended Silk Fabrics. Chemical Science International Journal, 33(3), 109–118. https://doi.org/10.9734/CSJI/2024/v33i3898*

samples were prepared accordingly to evaluate the tensile properties, colour fastness to rubbing, perspiration, washing & light and colour strength. According to the findings, reactive dyeing had a larger percentage of strength loss than Lanaset and acid dyeing. Relative to other materials, acid-dyed fabrics required less washing, according to fastness data. However, reactive dyed fabrics did not perform well when it came to perspiration fastness. Lanaset dyed fabrics reacted faster to light than other types due to the presence of metal ions. The studies also showed that materials colored reactively had stronger color retention. This attempt shall provide the blue print for the industry to emulate in the future.

Keywords: Acid dyeing; colour fastness; lanaset dyeing; reactive dyeing; tasar silk fabric.

1. INTRODUCTION

For thousands of years, silk, a natural fibre, has been an intrinsic part of Indian culture and traditions.The silk worm is the source of silk fiber, which is a continuous protein filament. Silk is known as the "Queen of Textile Fibre" universally because it is anti-allergenic, environmentally friendly and a symbol of beauty. This fine filament fibre is well-known for its insulating properties, water absorption, dyeability, glossy texture, and heat endurance. The primary constituents of natural raw silk are sericin and fibroin. Mineral salts and water make up the remainder. In hot water, a single protein known as fibroin remains insoluble. Sericin, on the other hand, is more water soluble than fibroin since it is mostly amorphous and acts as a gum binder to keep the cocoon structurally intact. All four commercial forms of silk—Mulberry, Tasar, Muga, and Eri—are manufactured exclusively in India; the latter three are collectively known as "Vanya/ Wild silk". Tasar, commonly known as tussah silk, is the most important form of wild silk. Tasar silk is becoming increasingly popular due to its durability, distinct sheen, rustic appearance, and environmentally-friendly manufacturing process [1]. Wild silk and mulberry silk have unique amino acid compositions. Tasar silk has a greater Alanine, Glycine, Serine, Tyrosine, and Aspartic acid content than mulberry silk[2]. Wild silk fibres feature a large concentration of amino acids with bulky side groups; they have greater elongation values but poorer tenacity than mulberry silk fibres [3].

While there has always been a demand for Tasar fabrics in their original colours,there are limits to the number of designs and fabrics available. The younger generation needs 100% Tasar material in a range of goods with distinctive designs and colour combinations; as a result, the Tasar fabric must now be dyed a certain hue. The Tasar silk has a pH 5.0 iso-electric point and a somewhat cationic character; it can be dyed with anionic dyes such as acids, metal complexes, reactive dyes, and certain direct dyes [4]. However, the primary goal of colouring a textile fibre is to ensure its permanence and prevent damage to the fiber's inherent abstract nature. This suggests that processing, such as washing, light, rubbing, and perspiration, shouldn't remove its hue. So, the dyestuff used for silk dyeing must be sustainable [5].

Silk, due to its protein make-up, is typically dyed with acid and reactive dyes for vibrant colours and ease of application. Reactive dyes are popular due to their vibrant hues, excellent durability, and low cost. Reactive dyes are differentiated from other types of dyes in textiles by their capacity to create covalent connections with the substrate to which they are applied, resulting in dye persistence. This covalent bond has strength greater than that of hydrogen bonds, ionic bonds, and van der Waals forces of attraction [6]. Silk is the second most common textile fibre to be coloured with acid dyes, behind wool, since it creates extremely brilliant colours and has good fastness qualities. Since acid dyes are powerful acid salts that dissolve in water, they provide neutral solutions and function as potent electrolytes in aqueous solutions. The main, though not exclusive, bond that forms between the dye and the fiber macromolecule is an ionic link. Other portions of the coloured ion and the fiber undergo further bonding. Compared to ionic connections, these secondary bonds—which include hydrogen bonds and van der Waals forces—are incredibly weak. The total amount of dye and fiber binding increases with the number of these secondary connections. As a result, larger dye molecules with more of these secondary linkages will exhibit superior fastness against laundering and wet treatments [7]. The Lanaset dye includes 1:2 metal complex and reactive dyes with excellent fastness and nearly comparable dyeing characteristics. A pH of 5-6 is used for all shadow depths. Lanaset is a very beneficial addition to the dyers because of its deep rich colours that are easy to combine together. On silk, they offer outstanding wash fast properties. Lanaset require the addition of auxiliaries chemicals to assist in establishing and maintaining the dye bath at the preferred pH.

This study compared the dyeing behaviours of Acid,Lansaet and Reactive dye on Tasar fabric and Tasar-blended fabrics in terms of tensile, colour strength and colour fastness characteristics. Colour fastness, defined as a dyed or printed textile's ability to retain its colour under a variety of conditions during production and actual use. The resistance to washing, rubbing, light, and perspiration (both basic and acidic) was evaluated [8]. However, given the current situation, it is imperative that the Tasar Silk Industry comprehend how the fastness properties of Lanaset, Acid, and Reactive dyes are imparted to both pure Tasar fabrics and Tasar-blended fabrics.

2. METHODOLOGY

2.1 Materials

Vanya Silk Reeling Division (VSRD) and Mulberry Silk Reeling Division (MSRD) of Central Silk Technological Research Institute (CSTRI), Central Silk Board (CSB), Bengaluru provided raw Wet reeled Tasar silk yarns and raw Mulberry silk yarns respectively. 500 grams of Glauber's salt, 100 grams each of Acid Dye (Red, Yellow Blue), Reactive Dye (Red, Yellow, Blue), and Lanaset Dye (Red, Yellow, Blue). 500 grams of soda ash, 200 grams of sodium acetate, 1000 ml of 100% w/v acetic acid, and 50 grams of soap were obtained from Wet Processing Division, CSTRI, CSB, Bengaluru.

2.2 Fabric Preparation

Tasar x Tasar and Tasar x Mulberry fabrics are prepared in Weaving Division of CSTRI, CSB, Bengaluru. The fabric details are shown in Table 1.

2.3 Tasar Silk Degumming cum Bleaching Process

Silk degumming cum bleaching process is applied on both Tasar x Tasar & Tasar x Mulberry fabric as per the optimized recipe mentioned in the Table 2 [9].

Initially, an electronic balance was used to weigh the raw fabrics. Water for the bath was filled to the necessary level as per the material to liquor ratio. The necessary amount of H_2O_2, Na_2SiO_3, Soap, Na_2CO_3 and anti-foaming agent was then poured to the bath and thoroughly dissolved. The fabric was put to the bath after the pH was measured. After then, the bath's temperature increased to 90 ℃ and stayed there for 30 minutes. The fabric was removed from the bath after 30 minutes, cleaned with hot water for 5 minutes. Next, set up a hot water bath with acetic acid and wash the yarn for 5 minutes. After taking the fabric out of the bath, wash it again in hot water for 5 minutes. Remove the fabric from the bath and dried it using woven dryer. The weight loss was then calculated after determining the dried weight of the degummed cum bleached fabric.

Table 1. Fabric details of tasar x tasar & tasar x mulberry fabric

Particulars	Tasar x Tasar	Tasar x Mulberry
Tasar Warp Yarn Avg Denier (Twist- 400 TPM, Z Twist, Tenacity – 2.60 g/d, Elongation–29 %)	70	70
Tasar Weft Yarn Avg Denier (70 d, Two Ply, zero twist)	140	-
Mulberry Weft Yarn Avg Denier (45 d, 3 ply, Twist- 400 TPM, Z Twist, Tenacity – 3.38 g/d, Elongation – 17.80 %)	-	138
EPI	74	72
PPI	61	62
Reed	72	72
Width (Inch)	35.5	35.2
Avg Fabric Wt. (GSM)	61	59
Thickness of the fabric (mm)	0.26	0.27
Fabric woven (meter)	16 mtr.	15.5 mtr.

2.4 Tasar Silk Dyeing Procedure

Fig. 1, Fig. 2 and Fig. 3 depicts the dyeing cycle of acid, Reactive and Lanaset dyeing respectively [10].

2.5 Sample Preparation

Degummed & bleached Tasar x Tasar & Tasar x Mulberry fabrics are dyed using 2% blue colour dye shade of Acid, Reactive &Lanaset dye respectively The samples are prepared as per below Table 3 for the testing purposes.

2.6 Testing Methods

2.6.1 Tensile strength

Using computerized tensile strength equipment called the "Universal Strength Tester (UTM)," the tensile qualities of dyed Tasar x Tasar & Tasar x Mulberry textiles are evaluated in the warp and weft directions in accordance with ASTM D5034 [11]

2.6.2 Colour fastness

The coloured samples were tested for a variety of fastness qualities according to ASTM guidelines. Washing fastness (AATCC 61), rubbing fastness (AATCC 8-1995), perspiration fastness (AATCC TM 15-2002), and light fastness (AATCC 16-1987) are specific test techniques and standards [12-14].

2.6.3 Assessing the chromatic values and colour strength of dyed samples

Colour strength is the extent to which a dye can impart colour to a material. The visible spectrum's light absorption is used to calculate the intensity of each colour. Relative colour strength is the percentage difference between the K/S values for samples and a standard at the same wavelength. "K" and "S" are the absorption and scattering coefficients of the coloured material, respectively. Using the Kubelka- Munk equation, relative colour strength (K/S) is determined from reflectance, R as follows in the equation (1)

$$\frac{K}{S} = \frac{(1-R)^2}{2R} \quad (1)$$

The colour measuring spectrophotometer was used to measure the colour intensity (K/S value) and CIELAB colourimetric values (L*, a*, b*) of the samples at 100 observers using the illuminant D-65 [15].

Table 2. Recipe for silk degumming & bleaching process

Particulars	Recipe
M:L	1:30
Hydrogen Peroxide (H_2O_2) 30% w/v	18 cc/l
Sodium Silicate (Na_2SiO_3)	5 g/l
Sodium Carbonate (Na_2CO_3)	1 g/l
Soap	5 g/l
Anti-foaming agent	1 g/l
Acetic Acid 100% w/v	2 cc/l
Temperature	90℃
Time duration	30 mins
pH	8-10

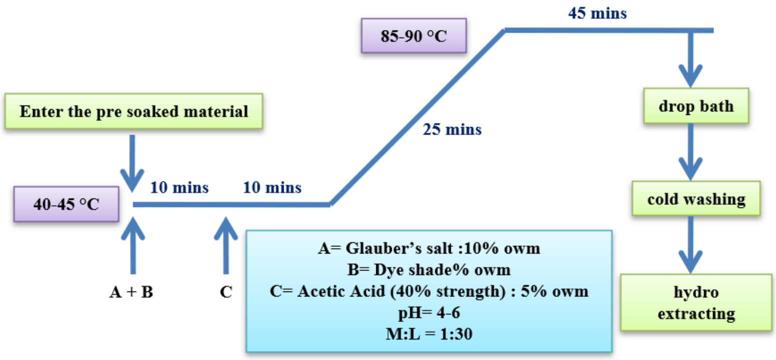

Fig. 1. Acid dyeing cycle

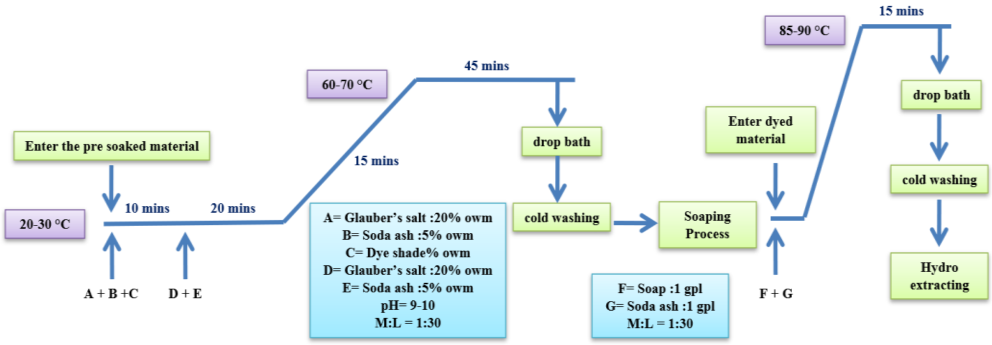

Fig. 2. Reactive dyeing cycle

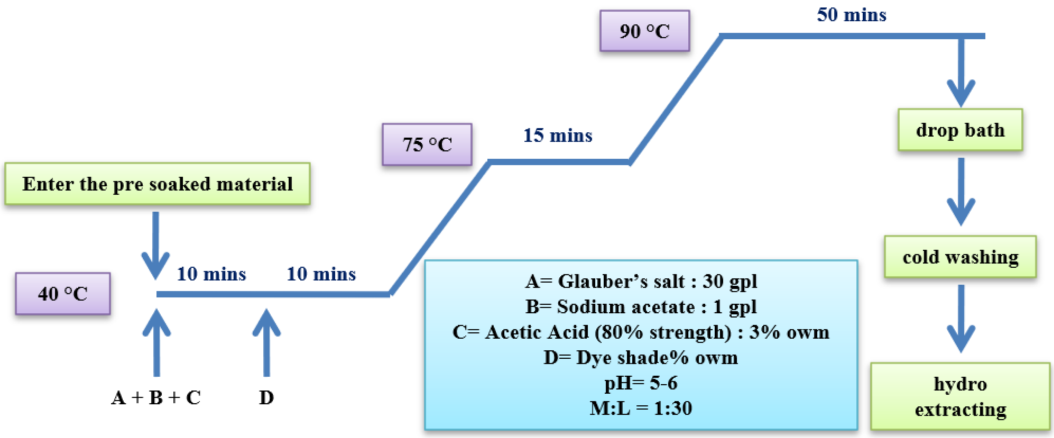

Fig. 3. Lanaset dyeing cycle

Table 3. Fabric samples details along with sample code

Sl No	Sample Code	Fabric Details	Dyeing Process
1	T-T-A	Tasar x Tasar	Acid
2	T-M-A	Tasar x Mulberry	Acid
3	T-T-R	Tasar x Tasar	Reactive
4	T-M-R	Tasar x Mulberry	Reactive
5	T-T-L	Tasar x Tasar	Lanaset
6	T-M-L	Tasar x Mulberry	Lanaset

3. RESULTS AND DISCUSSION

3.1 Observation of Weight Loss %

The effect of weight loss % observed on both Tasar x Tasar & Tasar x Mulberry fabric after degumming cum bleaching (D&B) process and tabulated in the Table 4.It was reflected that the weight loss % was higher in Tasar x Mulberry fabrics than Tasar x Tasar fabrics. This was may be due to the removal of high sericin content from Mulberry because it was well known fact that the sericin content in Mulberry silk was higher than Tasar silk.

3.2 Observation of Tensile Properties

The breaking loads (kgf) and breaking elongation % of Tasar x Tasar &Tasar x Mulberry dyed fabrics were evaluated by UTM and tabulated in the Table 5.

It was observed from the Fig. 4 that strength loss of Tasar x Mulberry fabric was higher than Tasar x Tasar fabrics as compared to the control sample due to the removal of high sericin content from the blended fabrics which result in loss of mechanical strength of the fabrics. It was noticed that strength loss was higher in case of reactive dyed-fabrics followed by Lanaset and acid dyed fabrics. This was due to the effect of pH in the dyeing bath. Reactive dyeing could be done at pH level of 9-10 which was alkaline condition whereas acid and Lanaset dyeing had conducted at acidic pH. The silk strand swelled in alkaline solutions. The reason for this was that the alkali molecules had partially separated the silk polymers. The polymer system of silk was held together by hydrogen bonds, salt linkages, and van der waal's forces. The alkaline solution easily dissolved the silk because the alkali hydrolyzed all of these inter-polymer forces of attraction. Thus the acid-dyed fabrics showed negligible strength loss as compared to others. It was further reflected from the results that the dyed fabric strength loss at weft way direction was lower than warp way direction in case of both Tasar x Tasar and Tasar x Mulberry.

Table 4. Weight loss% of tasar x tasar & tasar x mulberry fabrics

Fabric Sample No	Tasar x Tasar			Tasar x Mulberry		
	Before D&B	After D&B	Weight Loss %	Before D&B	After D&B	Weight Loss %
1	16.20	15.25	5.86	15.15	12.87	15.05
2	17.22	16.27	5.52	15.70	13.37	14.84
3	17.20	16.13	6.22	15.16	13.06	13.85
4	16.80	15.64	6.90	15.62	13.29	14.92
5	17.50	16.49	5.77	15.34	13.12	14.47
	Avg		6.06	Avg		14.63

Table 5. Breaking load &breaking elongation of tasar x tasar & tasar x mulberry dyed fabrics

Sample Code	Breaking Load (kgf)		Breaking Elongation %	
	Warp Way	Weft Way	Warp Way	Weft Way
T-T (Control)	23.88	34.26	32.55	26.75
T-T-A	22.43	32.53	36.41	28.71
T-T-R	21.01	30.23	39.05	30.64
T-T-L	21.73	32.42	36.4	27.82
T-M (Control)	24.51	43.73	34.3	12.42
T-M-A	20.98	38.23	35.89	13.44
T-M-R	18.28	34.59	39.87	16.03
T-M-L	19.44	37.35	37.67	13.86

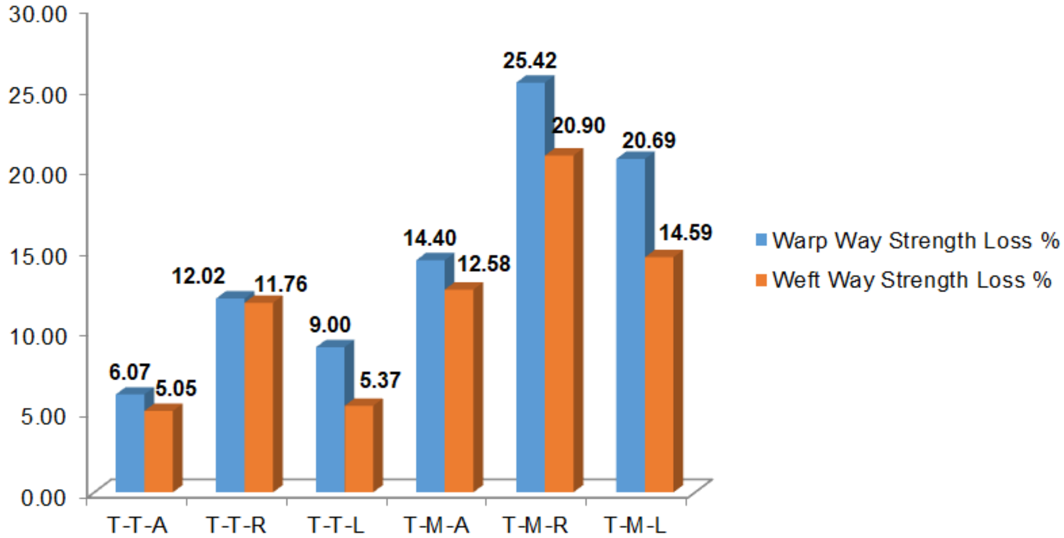

Fig. 4. Effect of strength loss % of tasar x tasar & tasar x mulberry dyed fabrics

It was observed from the Fig. 5 that there was a significant effect on breaking elongation % of both Tasar x Tasar and Tasar x Mulberry fabrics as compared to the control samples after dyeing with Acid, Reactive &Lanaset dyes respectively. This was because of the capacity of the chain molecules to revert to their original shape was lost as a result of the degradation of their orientation during degumming cum bleaching process as well as dyeing process. It was well known that compared to Mulberry silk, Tasar silk elongates more at the break which also showed in weft direction of Tasar x Mulberry fabrics. The lack of direction and structure contributed to the inability of molecular chains to form securely during fiber development. The sequence and composition of amino acids could affect the dense packing of chains in fibroin. Research had indicated that Tasar silk contains a higher percentage of bulky side group amino acids, including alanine. If there were more substantial side groups present, the molecular segments in the amorphous areas would mobilize more readily.It was further noticed that breaking elongation is higher in case of reactive dyed fabrics followed by Lanaset and acid-dyed fabrics as compared to the control samples in both Tasar x Tasar and Tasar x Mulberry fabrics.

3.3 Colour Fastness

The results after the assessment of colour fastness to rubbing, washing, light and perspiration of dyed Tasar x Tasar and Tasar x Mulberry fabrics were tabulated in the Table 6.

It was seen that there were no significant changes observed in rubbing fastness in both dry state and wet state of both Tasar x Tasar fabric as well as Tasar x Mulberry fabric as the values ranged between good to excellent in grey scale grading.

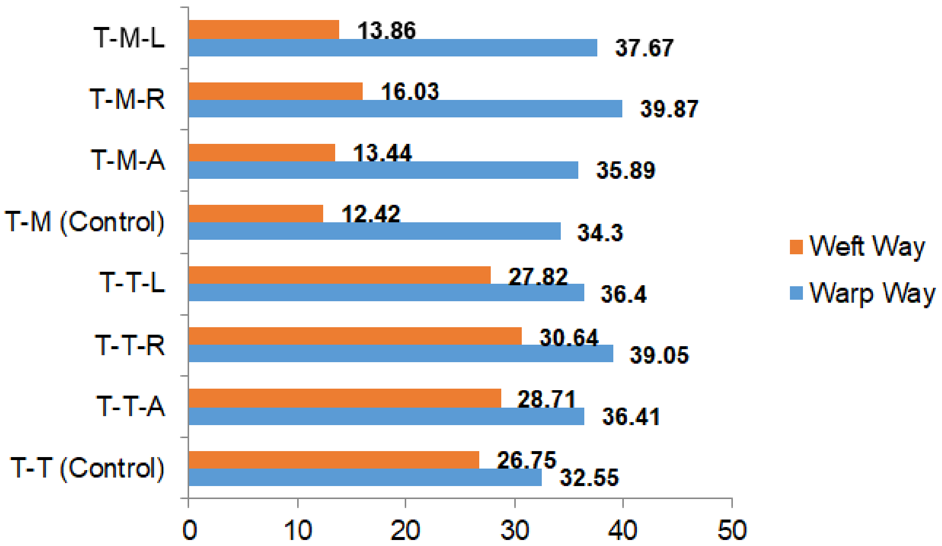

Fig. 5. Effect of breaking elongation % of tasar x tasar & tasar x mulberry dyed fabrics

Table 6. Assessment of colour fastness of tasar x tasar & tasar x mulberry dyed fabrics

Sample Code	Rubbing		Washing			Light	Perspiration					
							Stain (1-5)				Colour Change (1-5)	
	Grade (1-5)		Stain (1-5)		Colour Change (1-5)	Colour Change (1-8)	Cotton		Silk			
	Dry	Wet	Cotton	Silk			Acid	Alkali	Acid	Alkali	Acid	Alkali
T-T-A	5	4/5	4/5	5	2/3	4	4/5	4	4	3/4	4/5	4/5
T-T-R	5	4	4/5	5	3/4	4	4/5	3/4	4/5	5	3	2/3
T-T-L	4/5	4/5	4/5	5	3	6	5	4/5	4/5	4/5	4	3/4
T-M-A	4/5	4/5	4/5	5	3	5	4/5	4	4/5	3/4	4	3/4
T-M-R	5	4/5	4/5	5	4/5	5	5	4	4	3	3	2
T-M-L	5	5	4/5	5	3/4	7	5	5	4/5	4/5	4/5	4

It was showed from the Table 6 that the washing fastness of acid dyed fabrics was poorer than the reactive dyed fabrics. Because of the ease with which dye molecules migrate into and out of the fibre, acid dyes exhibited low washing fastness. On the other hand, the covalent bond formed between the dye and the fiber contributed the excellent washing fastness for reactive dyed fabrics. It was further noticed that the washing fastness of Lanaset dyed fabrics were slightly better than the Acid-dyed fabrics but lesser than the Reactive dyed fabrics. Lanaset dyes stand out for their ability to form complexes with metal ions, enhancing their affinity for fibers. The colour fastness to washing value showed poor to fair for Acid dyed fabrics whereas reactive dyed fabrics showed good to excellent.

When UV radiation passed through the fiber and causes photo-degradation processes including photo-oxidation and photo-tendering, silk exhibited a low level of resistance. It was observed that Lanaset-dyed fabrics showed higher fast to light than acid and reactive dyed fabrics. Lanaset dye is a compound of metal complex and reactive dye where the presence of metal ions plays an important role. It could absorb UV light and converted it to heat energy, which gave greater fading resistance to light. It was also noted that light fastness of Lanaset-dyed Tasar x Mulberry is slightly higher than dyed Tasar x Tasar fabrics. There were no significance differences observed in the light fastness of both acid and reactive dyed fabrics.

The perspiration fastness in alkaline media had greater impact on dyed silk fabrics than acidic media. It was reflected from the Table 6 that the perspiration fastness in both acidic and alkaline conditions of Tasar x Tasar and Tasar x Mulberry fabrics were found to be less when samples are dyed with reactive dye and the values were ranged between poor to good. In case of Acid and Lanaset-dyed fabrics, there were no significant changes observed on perspiration fastness, the fastness showed between good to excellent.

3.4 Colour Strength

The chromatic values (L, a, b) and K/S of dyed Tasar x Tasar and Tasar x Mulberry fabrics are calculated and reported in the Table 7.It was observed from the Fig. 6 that the colour strength of dyed Tasar x Mulberry fabric was slightly higher than Tasar x Tasar. It was further noticed that Reactive dyed fabric shows higher colour strength than Acid and Lanaset dyed fabrics.

Table 7. Assessment of chromatic values and colour strength of tasar x tasar fabrics

Sample Code	L	a	b	%R	K/S
T-T-A	40.96	7.77	-48.30	48.54	23.28
T-T-R	73.79	-11.48	0.63	66.59	32.30
T-T-L	49.40	-2.73	-32.06	53.38	25.70
T-M-A	42.91	8.32	-51.86	54.63	26.32
T-M-R	73.51	-12.24	-9.00	67.08	32.55
T-M-L	50.62	-2.03	-34.67	55.35	26.68

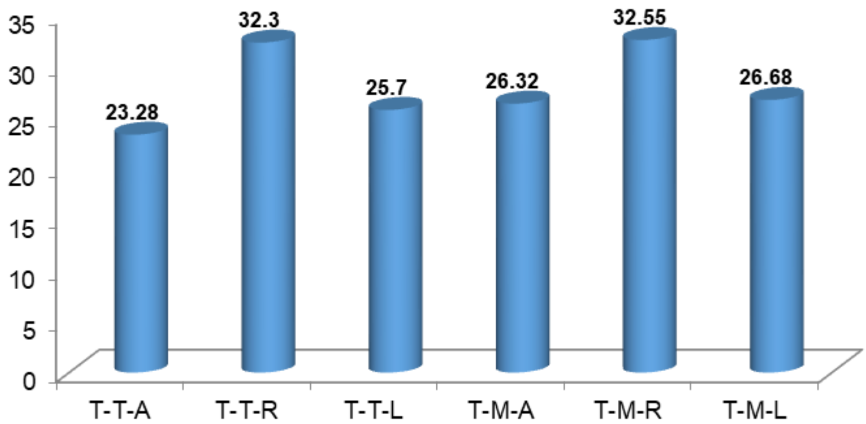

Fig. 6. Effect of colour strength on tasar x tasar & tasar x mulberry dyed fabrics

4. CONCLUSION

In this study, effects of Acid, Reactive and Lanaset dyed Tasar x Tasar fabric and Tasar x Mulberry fabrics were investigated by tensile properties (breaking load and breaking elongation), fabric colour fastness (washing, Perspiration, light and rubbing) and colour strength. It was observed that the weight loss of Tasar x Mulberry fabric was higher than Tasar x Tasar fabric after degumming cum bleaching process due to the removal of high sericin content from Mulberry resulted in higher strength loss. The strength loss was higher in case of reactive dyed fabrics followed by Lanaset and acid-dyed fabrics due to the effect of pH in the dyeing bath. There was a significant effect on breaking elongation % of both types of fabrics as compared to the control samples after dyeing with Acid, Reactive &Lanaset dyes respectively. Acid coloured textiles have a lower washing fastness than reactive dyed fabrics because dye molecules could easily migrate into and out of the fibre. The washing fastness of Lanaset dyed fabrics were slightly better than the Acid-dyed fabrics but lesser than the Reactive dyed fabrics. There were no significant changes observed in rubbing fastness of both Tasar x Tasar fabric as well as Tasar x Mulberry fabric but in case of perspiration, reactive dyed fabrics showed the least results. The perspiration fastness had a greater impact on silk fabrics under alkaline condition. Lanaset dyed fabrics showed higher light fastness properties than Acid and Reactive dyed fabrics due to the presence of metal ions. Colour strength (K/S Value) of reactive dyed fabrics was higher.The industry will be able to follow this initiative as a model in the future.

ACKOWLEDGEMENTS

The authorized research project CFC 07025 SI, "Studies on dyeing of Tasar silk yarn, fabric, and Tasar blended fabric," is the basis for the experimental work described in this publication. The funding for this research was provided by the Central Silk Board, Ministry of Textiles, Government of India, for which the authors are really grateful. They also thank the Director, Central Silk Technological Research Institute for his gracious support of the project.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/116866