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Assessment of colourfastness properties of eco-dyed and eco-printed mulberry silk fabrics

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Abstract
The present study was carried out to find the colourfastness properties of mulberry silk fabric. Mulberry silk fabric was dyed using natural dye extracted from tamarind (*Tamarindus indica* L.) seed dye. Two mordants namely alum as a metallic mordant and aloe vera as a natural mordant were used for this study. The surface of the dyed silk fabric was then enriched by using an eco-printing method. The dyed and printed samples were evaluated visually and with the help of greyscale for determining the colourfastness properties such as colourfastness to Sunlight, colourfastness to Washing, colourfastness to Crocking or Rubbing (Dry and Wet), colourfastness to Pressing (Dry and Wet), colourfastness to Perspiration (Acidic and Alkaline), which exhibited fair to good ratings with noticeable stained to negligible stained.

Keywords: Eco-dyeing, eco-printing, mulberry silk, mordant, colourfastness

Introduction
Colour is one of the fauna's components that make human life more appealing and aesthetically pleasing. In general, a dye is a coloured material that exhibits an inclination or attraction towards the substrate on which it is applied. The term "natural dye" refers to all colours derived from natural resources such as plants, insects, and animals [1]. *Tamarindus indica L.*, which is commonly known as tamarind tree belongs to the family fabaceae (Leguminosae) subfamily *Caesalpinioideae*, and is a significant multipurpose tree species in the Indian subcontinent [2]. The fruit pulp of tamarind has been used for a long time and the fruit has a hard brown shell when fully ripe. A huge amount of tamarind seeds are obtained as waste material from tamarind pulp industries [3]. These seeds must be treated well before developing eco-friendly and sustainable products [4]. The dye obtained from tamarind seeds is considered an adjective or mordant dye since it cannot bond directly to unmordanted material and requires the use of a mordant for application [5]. Silk has been intermingled with Indian life and culture and it has significant value due to its elegance, luster, sheen, strength, uniformity and excellent draping ability. *Bombyx mori* commonly known as mulberry silkworm produced a delicate cream-coloured white silk fiber which is the main commercial silk in the world [6]. Colouring of mulberry silk with various dyestuffs improves the quality of the fabric and its aesthetic appeal. The process of applying dyes or pigments on textiles, including fibers, yarns, and fabric, to achieve the desired colour with good colourfastness is known as dyeing. Eco-printing is both an art and a science, requiring technological expertise and compromise on process settings to achieve desired print effects. This type of printing utilizes natural colourants found in plants, fruits, vegetables, and by-products to produce visual effects through layering, tying, folding, clamping, or stitching metals rocks, twigs, etc. onto the substrate. Using mordants can improve the range of colours, change colour tones, increase the intensity of plant patterns, and boost the colour yield in the print [7]. In today's world, the increasing awareness of environmental and ecological well-being has brought natural dyes to the forefront. Value addition of the silk fabric through eco-dyeing and printing will lead to more consumer acceptance in the National or International market. Thereby, more profitability. Therefore, the investigator felt the necessity and made an effort to introduce the eco-dye and eco-print to enhance its aesthetic properties as well as demand in National and International markets.

2. Materials and Methods

2.1 Selection and collection of fabric

Mulberry silk (*Bombyx mori* L.) fabric was selected and collected from the Jorhat district of Assam, India for the study.

2.2 Selection of collection natural dye

Tamarind (*Tamarindus indica* L.) seeds were selected as a natural dye collected from the local market of Jorhat district of Assam.

2.3 Selection of mordant

Natural mordant aloe vera (*Aloe barbadensis miller)* and metallic mordant alum (*Potassium aluminum sulfate)* were selected for the study.

2.4 Preparation of fabric before dyeing

To make the fabric dyeable or printable, pretreatment is necessary before the dyeing to remove impurities like dust, dirt, etc. from the fibers. All contaminates that have a negative impact must be eliminated during the pretreatment procedure.

2.4.1 Degumming

The process of degumming involves eliminating the sericin or silk gum from the silk.

2.4.2 Procedure

Mulberry silk fabric was weighed accurately and immersed in the water. 5g of washing soda was added to the 1 liter of water and started heating at 60ºC temperature. After 30 minutes the fabrics were taken out and washed properly in running water and then air dried [8].

2.5 Nomenclature of the control, dyed and printed silk fabric

The nomenclature of the control, dyed, and printed silk fabric with different dyes, and mordants were presented in Table 1.

Table 1: Nomenclature of the control, dyed, and printed silk fabric

Sample Code	Fabric	Dye	Print	Mordant
C	Control	-	-	-
CT	Control	Tamarind seed	-	-
CTA_1	Control	Tamarind seed	-	Alum
CTA_2	Control	Tamarind seed	-	Aloe vera
$DMEA_1$	Dyed fabric with alum mordanted	Manjistha	Eco-print	Alum
$DMEA_2$	Dyed fabric with aloe vera mordanted	Marigold	Eco-print	Alum

2.6 Preparation of natural dye and mordant

2.6.1 Processing of Tamarindus indica L. dye

Processing starts with the cleaning of tamarind seeds with the help of water to remove the adhering dirt and impurities and was dried at room temperature and weighed. Then the seeds were roasted at 100 ºC for 10 min on an electric stove. They were pounded, ground, and sieved through the screen. The powder was stored at room temperature for further work [5].

2.6.2 Extraction of natural mordant

Aloe vera gel was used as a natural mordant to dye the selected mulberry silk fabric. Fresh leaves of aloe vera were washed thoroughly, the outer green surface was peeled off and a liner white mass was collected and crushed solid consistency which produces highly viscose liquid [9].

2.7 Optimization of dyeing condition

A series of experiments were conducted to optimize the different dyeing conditions namely dye extraction medium, dye extraction time, dye material concentration, dyeing time, mordant concentration, mordanting time, mordanting method, etc. for dyeing of mulberry silk fabric with Tamarind seed dye.

2.8 Dyeing of mulberry silk fabric

To dye the mulberry silk fabric, it was first weighed, and the extracted dye liquor was prepared at a material-to-liquor ratio of 1:30. The dye liquor's optical density was measured. The fabric was then immersed in the dye liquor and dyed for 60 minutes while occasionally stirring the dye bath. After dyeing, the fabric was removed, and the optical density of the liquor was recorded.

2.9 Eco printing

The process involves wrapping plant materials in cloth and then steaming or boiling the bundle to extract the natural dye from the plants and produced a contact print resembling the shape of the used leaf or flower

2.10 Evaluation of colourfastness properties of dyed and printed fabrics

All the dyed and printed samples of mulberry silk fabric were evaluated for, colourfastness to sunlight, colourfastness to washing, colourfastness to crocking or rubbing (dry and wet), colour fastness to pressing (dry and wet) and colourfastness to perspiration (acidic and alkaline) by using AATCC (1965) procedure and ASTM (1968) greyscale.

Sample	Shade
CT	

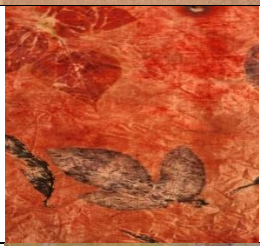
CTA_1	
CTA_2	
$DMEA_1$	
$DMEA_2$	

Plate 1: Colour shades of dyed and printed mulberry silk fabric.

3. Results and Discussion

3.1 Evaluation of Colourfastness properties of dyed and printed silk fabrics

Data obtained from Table 2, Samples CTA1 and CTA2 showed good colourfastness to sunlight while samples CT, DMEA1, and DMEA2 showed fair colourfastness to sunlight. The degree of colour fastness of sunlight can be divided into different levels and many factors can affect the colourfastness of sunlight, such as fiber materials, dye, colour combinations, the atmospheric composition of the surroundings, sample moisture content ratio, temperature, etc. [11]. The light fastness of a dye is influenced not only by its chemical constituents but also by several other factors. These factors include the physical state of the dye within the substrate, the types of bonds formed between the dye and the fiber, the nature of the substrate, the source and intensity of radiation, temperature and humidity conditions, the presence of foreign substances, atmospheric contaminants as well as after treatments given to improving performance characteristics of the dyed yarn/fabrics [10].

All the samples except CT exhibited good colourfastness to washing for colour change. On the other hand, in samples CTA1, CTA2 and DMEA1, and DMEA2, no staining occurred while sample CT showed slightly stained during washing. This can be explained that the good fastness to washing for the sample dyed might be due to the affinity of colouring component through H- bonding and van der waals forces. The washing fastness is influenced by the rate at which dye molecules diffuse and their distribution within the fiber. Dyes have a tendency to form aggregates inside the fibre, and the larger dye molecules tend to exhibit better wash fastness. In addition, in the case of samples treated with mordants, the interaction between the dye and the mordant contributes to the insolubilization of the dye, making it colour fast [12] [13].

In case of crocking or rubbing fastness, Samples CTA1, and CTA2 exposed good colourfastness and negligible staining while both eco-printed samples (DMEA1 and DMEA2) and CT showed a very fair colour fastness and slightly stained occurred in both dry and wet crocking. All the samples showed good colourfastness and negligeable colour stained in both dry and wet pressing. All the samples had fair to very fair colourfastness ratings to perspiration, however, both acidic and alkaline conditions caused some noticeable staining to slightly staining.

Table 2: Ratings for colourfastness properties of dyed and printed sample

Sl. No.	Test fabrics	Sunlight	Washing		Crocking				Pressing				Perspiration			
					Dry		Wet		Dry		Wet		Acidic		Alkaline	
		CC	CC	CS	CC	CS	CC	CS	CC	CS	CC	CS	CC	CS	CC	CS
1.	CT	3	4	4	4	4	4	4	5	5	5	5	3	3	4	4
2.	CTA_1	5	5	5	5	5	5	5	5	5	5	5	3	3	4	4
3.	CTA_2	5	5	5	5	5	5	4	5	5	5	5	4	4	4	4
4.	$DMEA_1$	3	5	5	4	4	3	3	5	5	5	5	3	3	3	3
5.	$DMEA_2$	3	5	5	4	4	3	3	5	5	5	5	3	3	3	3

4. Conclusion

The study aimed to effectively utilize waste material and reduce dyeing costs. Collecting the source material is convenient, and its dyeing process is environmentally friendly. Based on this study, it can be concluded that natural dyes and various shapes of leaves or other natural plant materials can be effectively used to dye and print the mulberry silk fabric which is eco-friendly, non-carcinogenic, and biodegradable. Though natural dyeing and printing have been known since ancient times as an artisanal practice, the chemistry of interaction of such colourants and prints with textile materials is a relatively recent area of interest for the production of eco-friendly textiles. It was clear from the present investigation that colourfastness properties of natural mordanted samples showed good fastness properties to sunlight, washing, crocking, and pressing as compared to metallic mordanted samples.

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