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# Dyeing of Silk Fabric with Eco-friendly Natural Dye obtained from *Opuntia ficus-indica* using Single Mordants

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## ABSTRACT

Natural dye was extracted from the flower of *Opuntia ficus-indica* and dyed onto bleached silk cloth. The dyed silk fabric's color intensity and color fastness properties were calculated and compared. According to the results of the dyed silk samples obtained, *Opuntia ficus-indica* in a simultaneous mordanting process with 3% mordant combination produced the best results.

**Keywords:** *Opuntia ficus-indica*; Silk; Fastness; Mordants; Natural dye.

## 1. INTRODUCTION

Natural dyes were the main colorants for textiles up to the end of 19th century. The discharge of dyeing industry effluents pollutes the environment, causing several pollution issues. Natural dyes have recently gained popularity as a result of stringent environmental regulations introduced by many countries in response to toxic and allergic reactions linked to synthetic dyes. All dyes were natural substances obtained primarily from plants and animals 150 years ago. Natural dyes found in plants and animals are pigmentary molecules that color fabrics. The present investigation focuses on the extraction of natural dye from the flower of *Opuntia ficus-indica*, which grows in all warm and damp parts of India. *Opuntia ficus-indica* (prickly pear) is a cactus species that has long been cultivated as a crop plant in agricultural economies in the world's arid and semi-arid regions. It is mainly cultivated as a fruit crop, but it is also used for vegetable nopales and other purposes. This is the species to which most culinary references to "prickly pear" refer. This cactus fruit is also known as "tuna." Cacti are excellent crops for dry areas because they easily transform water to biomass (Anderson 1971). Since its genetic relatives are found in central Mexico, the wild origin of *Opuntia ficus-indica* is most likely in Mexico.

## 2. MATERIALS AND METHODS

### 2.1 Materials

In this work we used conventionally de-sized, scoured and $H_2O_2$ (1%) bleached silk fabric (220 ends/dm, 180 picks/dm, 120 g/m$^2$), obtained from Dindigal district, TN, India. Analytical reagent grade ferrous sulphate, aluminium sulphate, nickel sulphate, potassium dichromate, stannous chloride, acetic acid, sodium chloride and sodium carbonate were used. In this work we made use of a natural mordant myrobalan (*Terminalia chebula*) as a nano powder. The color obtained on textiles from the flower of *Opuntia ficus-indica* extract varied depending on the mordant used.

**Fig. 1:** ***Opuntia ficus-indica.***

### 2.2 Methods

#### 2.2.1 Extraction of color component

The ethanol extraction of dye liquor was carried out under differing conditions, such as time of extraction, temperature of extraction bath and material-to-liquor ratio, to optimize (Kumaresan *et al.* 2018) extraction process. The optical density or absorbance value for the ethanol extract of plant parts was calculated using a Hitachi U-2000 UV-VIS absorbance spectrometer at a specific maximum absorbance wavelength (420 nm) in each event.

#### 2.2.2 Dyeing of silk fabrics with the extract of flower of *Opuntia ficus-indica*

The silk samples were wetted out and placed in dye baths with the appropriate amount of dye extract and water. After ten minutes, the required amounts of sodium carbonate and sodium chloride were added. The dyeing process took one hour at 60 °C. To prepare the dyed samples for pre-, simultaneous and post-mordanting with myrobalan and metallic salts, they were dried in the air without being washed.

#### 2.2.3 Pre-mordanting of silk fabric with myrobalan and metallic salts

Prior to dyeing, bleached silk cloth was mordanted at 60 °C for 30 minutes with 1-3 percent of each chemical mordant, such as aluminium sulphate, nickel sulphate, potassium dichromate, stannous chloride, copper sulphate and myrobalan, with a material-to-liquor ratio of 1:20. The dye extract was used to dye the samples that had been treated with metal salts.

#### 2.2.4 Simultaneous mordanting of silk fabrics with myrobalan and metallic salts

Bleached silk fabrics were treated concurrently with dye extract and metal salts at 60 °C for 30 minutes with a material-to-liquor ratio of 1:20, using 1-3 percent of any chemical mordant such as aluminium sulphate, nickel sulphate, potassium dichromate, stannous chloride, copper sulphate and myrobalan.

#### 2.2.5 Post-mordanting of silk fabrics with myrobalan and metallic salts

Dye extract was used to dye bleached silk fabrics. Wetted silk samples were placed in dye baths containing the appropriate amount of dye extract and water. The required amount of sodium sulphate was added after 10 minutes. The required amount of sodium chloride was added after 20 minutes. The dyeing took one hour at 50 °C. The dyed samples were taken out, squeezed and used for treatment with the metal salts without washing. The dyed silk samples were treated with different metal salts at 60 °C for 30 minutes using 1-3 percent of any of the chemical mordants, such as aluminium sulphate, nickel sulphate, potassium dichromate, stannous chloride, copper sulphate and the myrobalan, with a material-to-liquor ratio of 1:20.

After the dyeing, the dyed samples were repeatedly washed with water and then dried in air in all three methods. Finally, the dyed samples were soaped with a 2 gpl soap solution for 10 minutes at 50 °C, followed by repeated water washing and sun drying (Kumaresan *et al.* 2012).

#### 2.2.6 Determination of surface colour strength (K/Svalue)

The surface reflectance of the samples was measured using a Computer-aided Macbeth 2020 plus reflectance spectrophotometer, and the K/S values of the undyed and dyed silk fabrics were calculated using the Kubelka Munk equation:

$$K/S = \frac{(1- R_{\lambda\ max})^2}{2R_{\lambda max}} = \alpha\ C_d$$

where, K is the coefficient of absorption; S the coefficient of scattering; $C_d$ is the concentration of the due and $R_{\lambda max}$ is the surface reflectance value of the sample at a particular wavelength where maximum absorption occurs for a particular dye/color component.

#### 2.2.7 Evaluation of Color Fastness

The color fastness to washing of the dyed fabric samples was determined using a Sasmira Launder-O-Meter and the IS: 764 – 1984 wash fastness method. The wash fastness rating was evaluated using greyscale in accordance with ISO-05-A02 (loss of shade depth) and ISO-105-AO3 (extent of staining) and the results were cross-checked by measuring the loss of depth of color and staining with a Macbeth 2020 plus Computer-aided color measurement system equipped with relevant software. Color fastness to rubbing (dry and wet) was determined using an IS: 766-1984 crock meter and greyscale as defined by ISO-105-AO3 (extent of staining).

The color fastness to light exposure was determined using the IS: 2454-1984 method. Along with the eight blue wool standards, the sample was exposed to UV light in a Shirley MBTF Microsal Fade-O-Meter (with a 500 W Philips mercury bulb tungsten filament lamp simulating daylight) (BS 1006: BOI: 1978). Each sample's fading was compared to the fading of blue wool standards (1-8).

According to IS 971-1983 composite specimen, the test specimen was sandwiched between two adjacent pieces of silk fabric and stitched on all four sides to determine color fastness to perspiration. Separately, the samples were soaked for 30 minutes at room temperature in the test solution (acidic/alkaline) with MLR 1:50. The sample was then placed between two perspirometer glass plates under a 4.5 kg load (10 lb.). At 372 °C, the apparatus was kept in the oven for four hours. The specimen was removed at the end of this time and dried in the air at a temperature not more than 60 °C. Grey scales were used to grade the test samples for color change and staining (Pan *et al.* 2003).

## 3. RESULTS AND DISCUSSION

Tables 1, 2 and 3 show and compare the color intensity values of silk fabrics dyed with the flower of *Opuntia ficus-indica* obtained in this analysis using the single mordanting process.

*Opuntia ficus-indica* demonstrated better color intensity levels, according to the findings. The simultaneous process produced excellent results in all three dyeing processes. In all three methods of dyeing, the mordants ferrous sulphate and aluminium sulphate have shown excellent color strength values. The present research used mordant concentrations of 1%, 2%, and 3% for silk dyeing, in which the 3% mordant concentration produced the best results.

Table 4 compares the color fastness values of silk fabrics dyed with *Opuntia ficus-indica* flowers using a single mordanting method in this analysis.

**Table 1: Surface color strength of *Opuntia ficus-indica silk f*abric after pre-, simultaneous and post-mordanting methods by using 1% mordant concentration. K/S value without mordant: silk-1.48.**

| Mordant concentration:1% | K/S (λ=420 nm) | | |
|---|---|---|---|
| | Pre-mordanting | Simultaneous mordanting | Post-mordanting |
| Nickel sulphate | 1.51 | 2.49 | 2.13 |
| Aluminium sulphate | 1.53 | 2.86 | 2.66 |
| Potassium dichromate | 1.29 | 1.33 | 1.46 |
| Ferrous sulphate | 1.88 | 2.96 | 2.77 |
| Stannous chloride | 1.71 | 2.61 | 2.46 |
| Myrobalan | 1.25 | 1.31 | 1.30 |

**Table 2: Surface color strength of *Opuntia ficus-indica silk* fabric after pre-, simultaneous and post-mordanting methods by using 2% mordant concentration. K/S value without mordant: silk-1.48.**

| Mordant concentration:2% | K/S (λ=420 nm) | | |
|---|---|---|---|
| | Pre-mordanting | Simultaneous mordanting | Post-mordanting |
| Nickel sulphate | 1.50 | 2.52 | 2.22 |
| Aluminium sulphate | 1.81 | 2.87 | 2.67 |
| Potassium dichromate | 1.30 | 1.31 | 1.42 |
| Ferrous sulphate | 1.85 | 3.03 | 2.89 |
| Stannous chloride | 1.71 | 2.74 | 2.44 |
| Myrobalan | 1.23 | 1.28 | 1.32 |

**Table 3: Surface color strength of *Opuntia ficus-indica silk* fabric after pre-, simultaneous and post-mordanting methods by using 3% mordant concentration. K/S value without mordant: silk-1.48.**

| Mordant concentration:3% | K/S (λ=420 nm) | | |
|---|---|---|---|
| | Pre-mordanting | Simultaneous mordanting | Post-mordanting |
| Nickel sulphate | 1.46 | 2.52 | 2.23 |
| Aluminium sulphate | 1.82 | 2.91 | 2.74 |
| Potassium dichromate | 1.32 | 1.32 | 1.49 |
| Ferrous sulphate | 1.91 | 3.14 | 2.86 |
| Stannous chloride | 1.83 | 2.86 | 2.42 |
| Myrobalan | 1.29 | 1.39 | 1.41 |

**Table 4: Comparison of fastness properties and color strength of dyed cotton using single mordants.**

<table>
<tr><th rowspan="3">Plant parts used for dyeing</th><th rowspan="3">Mordant used</th><th rowspan="3">Method</th><th colspan="6">Properties</th></tr>
<tr><th rowspan="2">WF</th><th rowspan="2">LF</th><th colspan="2">RF</th><th colspan="2">PF</th></tr>
<tr><th>Dry</th><th>Wet</th><th>Acidic</th><th>Alkaline</th></tr>
<tr><td rowspan="5">Opuntia ficus-indica silk fabric</td><td rowspan="2">Ferrous sulphate (3%)</td><td>SM</td><td>5</td><td>4</td><td>5</td><td>5</td><td>5</td><td>5</td></tr>
<tr><td>PM</td><td>5</td><td>4</td><td>5</td><td>5</td><td>5</td><td>5</td></tr>
<tr><td rowspan="3">Aluminium sulphate (3%)</td><td>SM</td><td>4-5</td><td>4</td><td>5</td><td>5</td><td>5</td><td>5</td></tr>
<tr><td>PM</td><td>5</td><td>4</td><td>5</td><td>5</td><td>4</td><td>4</td></tr>
<tr><td>PM</td><td>5</td><td>5</td><td>5</td><td>5</td><td>5</td><td>5</td></tr>
<tr><td rowspan="2">Onosmaechioides</td><td>Ferrous sulphate (3%)</td><td>SM</td><td>5</td><td>2</td><td>5</td><td>5</td><td>4</td><td>5</td></tr>
<tr><td>Aluminium sulphate (5%)</td><td>SM</td><td>5</td><td>2</td><td>4</td><td>3-4</td><td>5</td><td>5</td></tr>
<tr><td>Fountain flower</td><td>Ferrous sulphate (3%)</td><td>SM</td><td>4-5</td><td>5</td><td>4-5</td><td>4</td><td>4-5</td><td>4-5</td></tr>
<tr><td rowspan="2">Mangifera indica</td><td>Ferrous sulphate (2.5%)</td><td>SM</td><td>5</td><td>4</td><td>4-5</td><td>4</td><td>5</td><td>5</td></tr>
<tr><td>Aluminium sulphate (12.5%)</td><td>SM</td><td>5</td><td>4</td><td>4-5</td><td>4</td><td>5</td><td>5</td></tr>
<tr><td rowspan="2">Colquhouniacoccinea</td><td>Ferrous sulphate (2.5%)</td><td>PM</td><td>4-5</td><td>4-5</td><td>5</td><td>5</td><td>5</td><td>5</td></tr>
<tr><td>Aluminium sulphate (12.5%)</td><td>PM</td><td>4</td><td>4</td><td>4</td><td>4</td><td>4</td><td>4</td></tr>
<tr><td rowspan="2">Pongamia pinnato</td><td>Ferrous sulphate (2.5%)</td><td>SM</td><td>-</td><td>5</td><td>4-5</td><td>4-5</td><td>-</td><td>-</td></tr>
<tr><td>Aluminium sulphate (12.5%)</td><td>SM</td><td>-</td><td>5</td><td>4-5</td><td>4-5</td><td>-</td><td>-</td></tr>
<tr><td>Neem tree bark</td><td>Aluminium sulphate (12.5%)</td><td>PM</td><td>3</td><td>2-3</td><td>4-5</td><td>4-5</td><td>-</td><td>-</td></tr>
</table>

**WF-Wash fastness, LF-Light fastness, PF-Perspiration fastness, RF-Rub fastness, CS-Color strength, PM-Pre-mordanting, SM-Simultaneous mordanting.**

## 4. CONCLUSION

The simultaneous method produced excellent results in all three dyeing processes. The mordants ferrous sulphate and aluminium sulphate produce excellent results in all three dyeing methods that use two plant sections. According to the results of the analysis of the dyed silk samples' fastness properties and color power, *Opuntia ficus-indica* in a simultaneous mordanting process with a 3 percent mordant combination produces the best results.

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## CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.



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