Chapter

Printing of Textiles Using Natural Dyes: A Global Sustainable Approach

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Abstract

Globalization has completely changed the fashion industry and its approach toward sustainability. Fast changing trends are majorly focused on synthetic dyes and fabrics. And these products have failed building the bridge between sustainability and environment-friendly designs. Therefore, this chapter is aimed at the approach toward design development and development of sustainable eco-friendly approach for screen printing by using natural dyes on fabrics like silk and cotton. The chapter is based on sustainable design approach which gives much provision for using natural dyes for everyday change in fashion. The chapter also focuses on color fastness properties of the used dyes. These results were evaluated by carrying out color fastness tests for light, wash, rubbing, and perspiration using standard testing methods. Design methodology used in the study also has the potential for skill development programs for entrepreneurs and also contributes to rural development programs by creating sustainable growth.

Keywords: natural dyes, indigo, sappanwood, madder, screen printing, eco-friendliness, sustainable approach, silk and cotton textiles

1. Introduction

The use of natural dyes has been in India for thousands of years and is part of India's cultural identity. In ancient times, dyed textiles were symbols of status and, because of their cost, were reserved only for the wealthiest classes. Dye sources were earlier extracted from plants, animals, and minerals. Madder and indigo were the major dyes used in India since 2500 BC. With the intervention of synthetic dyes, the use of natural dyes for textile dyeing has been reduced tremendously. Fast fashion demands low cost, simple, and reproducible dyeing or printing process. Both the synthetic dyes and natural dyes play a key factor for coloration and ornamentation of textile materials like silk and other fibers. Synthetic dyes are playing important and predominant role for coloring the majority of silk materials, while natural dyes are being specially used for developing uncommon soothing shades on silk yarns or fabrics in small-scale sector or rural sector, which is gradually gaining popularity due to its nontoxicity and eco-friendly character against possible unsafe ecotoxicity criteria of synthetic dyes [1, 2].

Textile printing in India has been practiced over centuries. Screen printing using natural dyes in India has helped in creating bridge between conventional printing techniques and mass production of textiles in an efficient way. In this chapter natural dyes such as madder, sappanwood, and indigo are used under optimized temperature, pH, and duration for extraction. The cotton and silk substrates are prepared for screen printing by scouring the fabrics. Screens are developed based on the patterns obtained by conventional shibori dyeing techniques. During printing process, madder, sappanwood, and indigo dye extract were used to provide color. More often it is assumed that color will change depending on printing methods and the substrate used. But in natural dyes, this expectation is somewhat high [3], and especially in printing processes, the effect of mordant type is of great importance for the shade of the color as printing is totally a different approach compared with dyeing of textiles. As a sustainable approach toward screen printing, mordants and binding agents used in this chapter are natural. 20% alum is used with madder and sappanwood extraction as metamordanting agent. Tamarind kernel powder is used as thickening agent for madder and sappanwood. Cornstarch is used as thickening agent for indigo.

2. Material and methodologies

2.1 Fabrics

Most of the studies available for dyeing with natural dyes relate to woolen textiles, and such studies on silk are still insufficient and that study on cellulose or lignocellulose textiles is scant. Hence, there is ample scope of undertaking an integrated study of the surface appearance, durability, dye intake, and screen printing of silk and cotton with selective natural dyes.

Silk and cotton fabrics have been considered for experimentation in this chapter. As silk fabrics are best available for commercial use, this delicate filament fiber is well known for its sheen, texture, water absorbency, dye affinity, thermal tolerances, and insulation properties [4]; its dyeability is one of the prime properties needed to analyze the screen printing of shibori designs using natural dyes.

2.1.1 Pretreatment for fabrics

Natural fabrics must be treated to ensure good dye absorbency before dyeing or printing to remove any natural or added impurities while manufacturing and handling the textile materials. Silk and cotton fabrics used in this experiment are treated for scouring, desizing, and degumming. Like in any other dyeing and printing processes, it was found that pretreatment process influenced the printability of cotton with natural dyes [5].

2.2 Dyes and mordants

Commercially available natural dyes like madder, sappanwood, and indigo are used for the experiments, which are sourced from KMA Exports, Tindivanam, Tamil Nadu. Dye sources used for this study are easily available, and the effluents are not hazardous for the human health and nontoxic to the ecosystem. Myrobalan and alum were used as metamordants while preparing the printing paste of madder and sappanwood. Alum is used to treat the fabrics for its low environmental toxicity [6].

2.2.1 Thickening agents

The thickening agents are tamarind kernel seeds and cornstarch.

2.2.2 Reduction of indigo

According to discovery of European wood vat reduction recipe from medieval manuscripts [7], it was found that a hitherto unknown bacterium, *Clostridium isatidis*, is responsible for indigo reduction; this bacterium reduces the indigo particles to soluble leucoindigo. As per the traditional indigo fermentation process, vat routinely requires the addition of red dye madder, which contains high concentration of anthraquinones; these quinines significantly increase the rate of indigo reduction by *C. isatidis*. As quoted by J N Liles in his book *The Art and Craft of Natural Dyeing*, in 1794, Bancroft suggested that the use of glucose alone will reduce the indigo and if reduction did not adequately occur, the addition of oxides of tin can be used. Hence, in this experiment instead of sodium dithionite, jaggery will be used along with sodium hydroxide to keep the vat alkaline.

Reduction with jaggery and madder: indigo cake was powdered, and 10 g was taken in a vat; 1 l of water was kept over water bath at temperature of 60°C, to which 20 g of madder and jaggery was added. About 4 g of sodium hydroxide was then added to the solution, and the solution is maintained at pH 12 by adding sodium hydroxide.

2.2.3 Dye extraction with madder and sappanwood

Dye extraction was carried out at acidic and neutral medium for madder and sappanwood at the temperature of 70°C for 60 min, where 15 g of madder and 15 g of sappanwood were used with two separate vessels containing 150 ml of water. When the extracted solution cools down to room temperature, 7.5 g of alum is added as metamordanting agent for both madder and sappanwood dye extract. Additionally, 15 g of myrobalan was added to madder dye extract solution as mordanting agent. Then the extracted solution of madder and sappanwood was steeped for 12 h, which was later stirred and filtered.

2.3 Printing paste preparation

To make printing paste of indigo, 100 ml water was taken in a beaker and 20 g of cornstarch is added and boiled, to which 100 ml of fermented indigo solution was added and left for further fermentation for 12 h.

To make printing paste of madder and sappanwood, 15 g of tamarind kernel seed powder was taken for each solution and mixed with constant stirring using an electric blender.

2.4 Printing technique

The printing process involves the printing pastes, fabrics, and the screen developed using shibori designs. Fabric is laid on a waxed wooden surface to ensure no movement of fabric while printing. The print paste is guided through the screen mesh or the open areas of the design on the fabrics by using a flexible rubber squeegee. A constant pressure is maintained while drawing the paste from one end to another and during each printing. The printed fabrics are then allowed to air-dry for 24 h.

2.5 Washing and fixing

Printed fabrics were washed with plain water to remove the cornstarch and tamarind seed kernel powder. Indigo samples were washed with cold water followed by hot water with constant stirring. Printed samples of madder and sappanwood were treated with dhawadi (*Woodfordia floribunda*) as postmordanting for fixing the color on to the substrates. Fixation was done at 60°C for 40 min followed by cold water rinse.

3. Testing and evaluation methods

3.1 Color parameters and color fastness properties

Dried samples were then analyzed further for color parameters and fastness according to the specified standards. **Figures 1** and **2** shows printed cotton and silk using indigo, **Figures 3** and **4** printed cotton and silk using madder, and **Figures 5** and **6** printed cotton and silk using sappanwood.

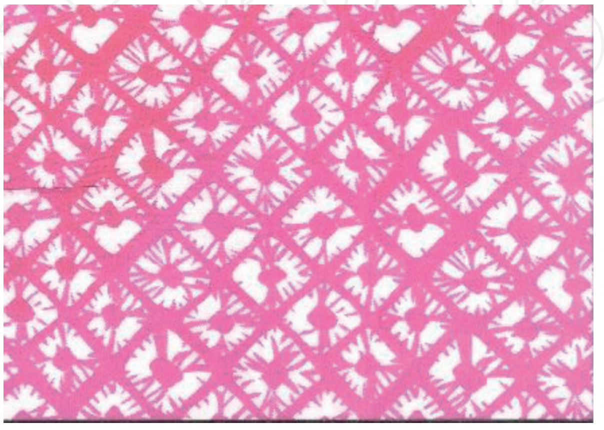

Figure 1.
Sappanwood on cotton fabric.

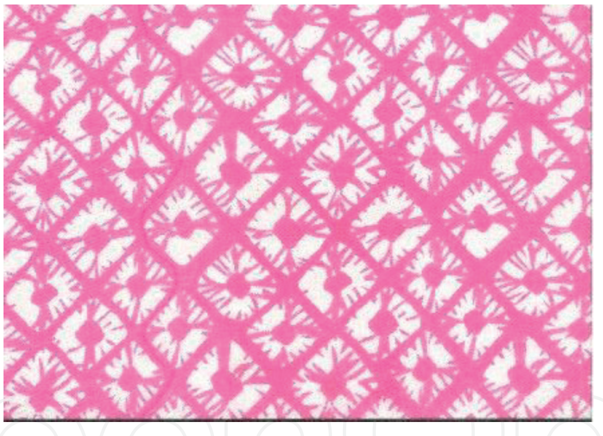

Figure 2.
Sappanwood on silk fabric.

Figure 3.
Madder on cotton fabric.

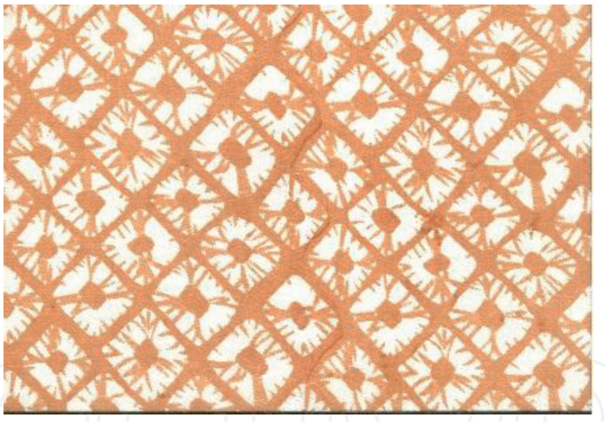

Figure 4.
Madder on silk fabric.

Figure 5.
Indigo on cotton fabric.

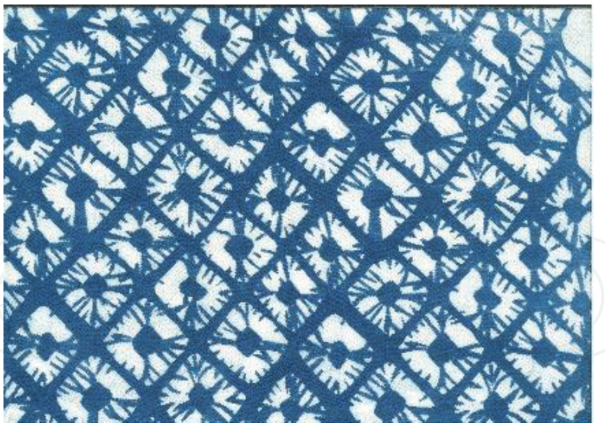

Figure 6.
Indigo on silk fabric.

3.1.1 Evaluation of CIE lab coordinates

Color value of the sample was analyzed based on L*a*b* values using reflectance spectra through spectrophotometer. The L* value is a measure of lightness and darkness of the color to define the color on a two-dimensional chromatic space of green-red axis and blue-yellow axis. Negative a* value indicates greenness in the screen printed samples and negative b* value indicates blueness in the screen printed samples, while positive a* value indicates redness and positive b* value indicates yellowness in the screen printed samples. L*, a*, and b* values were evaluated for five samples, and the average readings are recorded in **Tables 1**–**3**.

3.1.2 Measurement of color fastness properties

Color fastness to washing of dyed samples was determined by launder-o-meter in accordance with method prescribed in ISO 105-C02. Color fastness to rubbing was determined by crockmeter in accordance with method prescribed in AATCC crockmeter method [8]. Color fastness to light of dyed cotton and silk fabrics was assessed on IS 2454 1985. Light fastness of printed fabric is influenced by chemical and physical state, concentration of dye, nature of the fibers, and mordant type [9]. Color fastness to perspiration of dyed cotton and silk fabrics were determined by perspi-o-meter in accordance with method prescribed in ISO 105-E04:2013 test method. The data obtained are recorded in **Tables 4–6**.

Fabrics	Mordants	CIE color coordinates			Description
		L*	a*	b*	
Cotton	Simultaneous mordanting (alum)	59.44	30.14	−9.60	Lighter, more red, and more blue
	Postmordant (*Woodfordia floribunda*)	60.88	27.30	−11.49	Lighter, more red, and more blue
Silk	Simultaneous mordanting (alum)	56.53	40.13	−17.91	Lighter, more red, and more blue
	Postmordant (*Woodfordia floribunda*)	60.09	37.45	−8.23	Lighter, more red, and more blue

Table 1.
Color characteristics of sappanwood with mordanting.

Fabrics	Mordants	CIE color coordinates			Description
		L*	a*	b*	
Cotton	Simultaneous mordanting (alum)	61.21	13.84	19.14	Lighter, more red, and more yellow
	Postmordant (*Woodfordia floribunda*)	61.32	13.07	19.11	Lighter, more red, and more yellow
Silk	Simultaneous mordanting (alum)	67.69	13.53	11.29	Lighter, more red, and more yellow
	Postmordant (*Woodfordia floribunda*)	61.56	16.40	17.01	Lighter, more red, and more yellow

Table 2.
Color characteristics of madder with mordanting.

Fabrics	Reducing agents	CIE color coordinates			Description
		L*	a*	b*	
Cotton	Jaggery	38.90	−2.94	−22.10	Lighter, more green, and more blue
Silk	Jaggery	51.33	−1.17	−25.74	Lighter, more green, and more blue

Table 3.
Color characteristics of indigo with honey and jaggery.

Fabric	Mordants used	Fastness properties								
		Washing		Light	Perspiration				Rubbing	
		Change in color (cc)	Staining on cotton (cs)		Alkaline		Acidic		Dry	Wet
					cc	cs	cc	cs		
Cotton	Simultaneous mordanting (alum)	1/2	5	1	3/4	4	1/2	4	4/5	4
	Postmordant (*Woodfordia floribunda*)	1/2	5	1/2	3/4	4	1/2	4	4/5	4
Silk	Simultaneous mordanting (alum)	4	5	1/2	3/4	4	2	4/5	5	4/5
	Postmordant (*Woodfordia floribunda*)	3	5	1/2	3	4/5	2	4/5	5	4/5

Table 4.
Color fastness for sappanwood.

Fabric	Mordants used	Fastness properties								
		Washing		Light	Perspiration				Rubbing	
		Change in color (cc)	Staining on cotton (cs)		Alkaline		Acidic		Dry	Wet
					cc	cs	cc	cs		
Cotton	Simultaneous mordanting (alum)	4	5	2/3	4/5	5	4/5	5	5	4
	Postmordant (*Woodfordia floribunda*)	3/4	5	2/3	5	5	4	5	5	4
Silk	Simultaneous mordanting (alum)	4	5	2	4/5	5	5	5	4/5	3/4
	Postmordant (*Woodfordia floribunda*)	4	5	2	4/5	5	5	5	4/5	4

Table 5.
Color fastness for madder.

Fabric	Reducing agents	Fastness properties								
		Washing		Light	Perspiration				Rubbing	
		Change in color (cc)	Staining on cotton (cs)		Alkaline		Acidic		Dry	Wet
					cc	cs	cc	cs		
Cotton	Jaggery	4/5	4/5	3	5	5	5	5	4	3
Silk	Jaggery	4	5	2/3	4/5	5	4/5	5	4/5	3

Table 6.
Color fastness for indigo reduced with jaggery.

4. Results and discussions

It is indicated by CIE color coordinate results. The a* value indicates redness or greenness, and b* value indicates yellowness and blueness. From **Table 1**, it can be seen that a* values are positive which indicates redness and b* values are negative which indicates blueness in printed samples with both metamordanting and postmordanting agents. From **Table 2**, it can be seen that a* values are positive which indicates redness and b* values are positive which indicates yellowness in printed samples with both metamordanting and postmordanting agents. From **Table 3**, it can be seen that a* values are negative which indicates greenness and b* values are negative which indicates blueness in printed samples with both metamordanting and postmordanting agents.

The light fastness properties of printed cotton and silk fabrics dyed in sappanwood with alum and dhawadi (*Woodfordia floribunda*) as mordants (see **Figures 1** and **2**) are found poor which shows that dyes are unstable to photodegradation. Screen printed samples were evaluated for rubbing fastness. Rubbing fastness grades of dry rubbing are found very good to excellent, but for wet rubbing fastness, it is good. Washing fastness grades for color change for both mordants were found poor for cotton and average for silk, and color staining was observed to be good for all the samples. Washing fastness grades clearly reveal that color change was observed in both the mordants and very slight color staining was seen on cotton and silk fabrics. Screen printed samples showed moderate to good performance during alkaline perspiration test and poor performance during acidic perspiration test (see **Table 4**).

The light fastness properties of printed cotton and silk fabrics dyed in madder with alum and dhawadi (*Woodfordia floribunda*) as mordants (see **Figures 3** and **4**) are moderate which shows that dyes are slightly stable to photodegradation and printing paste interaction is good. Screen printed samples were evaluated for rubbing fastness. Rubbing fastness grades of dry rubbing are found very good to excellent, but for wet rubbing fastness, it is good. Washing fastness grades for color change for both mordants were found good for cotton and very good for silk, and color staining was observed 5 for all the samples. Almost all screen printed samples showed good to excellent performance during alkaline and acidic perspiration tests (see **Table 5**).

Data for color fastness to washing, rubbing, light, and perspiration of cotton and silk screen printed samples (see **Figures 5** and **6**) with natural indigo reduced using natural ingredients has found out during the study by following standard testing methods. The use of natural auxiliaries has resulted in good fastness rating on cotton and silk screen printed samples with indigo. Based on the result, the printed fabrics have good color fastness properties in terms of wash, light, and perspiration. Rubbing was found moderate to poor (see **Table 6**).

5. Conclusions

In the current world of fast fashion, there is an increased concern globally toward the use of hazardous and carcinogenic synthetic dyes like azo and benzidine; these dyes have irrevocable effects on nature and mankind. The growing awareness about sustainability and environment-friendly dyes has created an essential platform for young researchers to revive and experiment with traditional approach of textile dyeing and printing. However, the textile dyed from natural dyes does need value addition to reach the desired market acceptance; printing different motifs using natural dyes can help overcome the requirements of value addition for textiles. Natural dyes have always been preferred for its soothing colors; with the experiment and results obtained in this chapter, it can be seen that the screen printing on cotton and silk fabrics using indigo, madder, and sappanwood has resulted in promising colors and also can be considered as the recommendable alternative to harmful synthetic dyes. This chapter was focused on the application of conventional shibori patterns for screen printing using natural dyes. From the history of fashion, it is known that the comeback of green clothing is in high fashion. In addition, design process of textile design is also served as eco-route in this chapter. There is a huge scope to textile printing using natural dyes; new sources of natural dyes and new trends in fashion applications can create a global niche market for textiles and for natural dyes. This research can be an innovative method for textile design with screen printing. The major significance of this chapter was to add a value on textile by improving the esthetic functions and commercial values of fabric. The application of these techniques can serve as a new and complete method to create innovative fabric design.

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