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The effect of knit structure on natural dyeing properties of cotton fabric

Abstract

Natural dyeing of textile materials is gaining popularity all over the world since natural dyes are mostly eco-friendly, less toxic, and less allergenic as compared with synthetic dyes. Although synthetic dyes offer a broad range of color and color fastness and bright hues, they are nonbiodegradable and carcinogenic compounds and cause water pollution as well as waste disposal problems. This study presents the natural dyeing of cotton knitted fabric with three different structures using *R. cordifolia root* extract as a natural dye. Knitted fabrics with three different structures, interlock (350 g/m^2), single jersey (145 g/m^2) and rib (135 g/m^2), were produced and dyed with madder (*Rubia Cordifolia*) in the presence of tannic acid as a mordant. The dyed samples were evaluated in terms of color measurement results (CIE L*,a*, b*, C*, h^0, ΔE) and color fastness properties.

Keywords: natural dyeing, madder, single jersey, rib, 3-thead knit

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Introduction

Natural dyeing of textiles is attracting great attention due to the increased awareness in sustainability and environmental friendliness. Synthetic dyes, which are derived from non-renewable petroleum resources, are nonbiodegradable and carcinogenic compounds and cause water pollution as well as waste disposal problems. Natural dyes have emerged as an eco-friendly solution to the textile industry. Natural dyes, obtained from plants, insects/animals and minerals, are renewable and sustainable bioresource products with minimum environmental impact. Plants are the major sources of natural colorants and their parts such as stem, leave, fruits, seeds and pills are used for extracting natural color.[1–4]

Textile coloration has been done using extracts obtained from the roots of various plant species of the genus *Rubia* for centuries. *Rubia cordifolia* (Indian Madder) is an ethnic plant that grows near streams and rivers along the upper Ghats in evergreen forests. *Rubia cordifolia* produces anthraquinone reddish orange dyes in roots, stem and leaves, which has been used for dyeing textiles since ancient times. Anthraquinone dyes have poor affinity for cotton fibers, therefore their color fastness properties have been often enhanced by mordants. With the help of mordants, different colours and shades can be obtained with the same dye source. Metal salts that form an insoluble complex with dye molecules, including potassium aluminum sulfate (alum) and ferrous sulfate are used to enhance the affinity of natural dyes to textile fibers. However, they generate wastewater containing residual toxic metal ions, which cause severe negative impacts on the environment, health-related problems and allergic responses. Tannic acid is used as a biomordant, a replacement to metallic mordants.[5–11]

This study presents the natural dyeing of cotton knitted fabric with *R. cordifolia root* extract as a natural dye. The aqueous extract obtained from the powdered roots of Indian madder (*Rubia cordifolia*) was used for dyeing of cotton knitted fabrics with three different knitted structures; interlock, single jersey and rib. The dyed samples were evaluated in terms of color measurement results (CIE L*,a*, b*, C*, h^0, ΔE) and color fastness properties.

Materials and methods

In this study, Ne 30/1 open-end spun yarn with a yarn twist of 850 m/turn and a U value of 12.5% was produced using American cotton with a fiber fineness of 4.1 micronaire. Knitted fabric production was carried out on a Mayer circular knitting machine, a single plate knitting machine (15 pus 28 fine) and a double plate knitting machine (34 pus 18 fine). Knitted fabrics were produced in 3 different constructions: interlock (350 g/m^2), single jersey (145 g/m^2) and rib (135 g/m^2) structures.

Produced knitted fabrics with different constructions were dyed with madder (*Rubia Cordifolia*) in the presence of natural textile auxiliaries at 80 ^{0}C for 1 hour. Tannic acid was chosen for use as an eco-friendly mordant compared to other commonly used metal salt mordants. After dyeing, all dyed samples were washed with a soap solution (3.3 % VegeSuper).

Performance tests

Color measurement

Color measurement values (CIE L*, a*, b*, ΔE and tristimulus values) were determined using the Datacolor Spectraflash SF 600 Plus reflectance spectrophotometer.

Color fastness tests

Color fastness to washing, water, perspiration, rubbing and artificial day light were carried out according to the standard of ISO 105-C06:2010 (A2S), ISO 105-X12:2016, and ISO 105-B02:2014, respectively.

Washing fastness was conducted using ECE Detergent-B phosphate and sodium perborate with 10 steel balls in Gyrowash device.

Results and discussion

Color measurement results

Color measurement values were determined using the Datacolor Spectraflash SF 600 Plus reflectance spectrophotometer. The largest measuring plate with a diameter of 30 mm (LAV) was used. CIE Lab and tristimulus values obtained for the D65 light source and 10˚ standard observer are shown in Table 1.

Interlock fabric has the highest **L* value** (**83.60**) than the other two fabrics, indicating that it has lighter shade compared to the single jersey and rib fabrics. Interlock fabric has lower redness (**a*=9.04**) and yellowness (**b*=10.68**) values compared to the other two fabrics.

Additionally, interlock fabric has a lower saturation value (**C*=13.99**) than others, meaning that it is visually perceived as less vivid. This is due to the fact that the interlock fabric has a higher unit weight (350 g/m²) and, therefore a tighter structure than the other two fabrics. The dyestuff absorption was lower in the fabric with a tighter structure, resulting in lower dyestuff uptake. Interock knitted fabric has the highest **ΔE value** (**11.339**), which is associated with the tightness of the fabric sample. Interlock fabric is created using two sets of needles, resulting in a thicker fabric. These two layers are connected by stitches that interlock with one another, which makes it stronger, more durable, and thicker than single jersey and rib fabric. The **h°** angle shows that the colors of all three fabrics are in the same region (1st region) in the 3D color space system.

Total color difference (ΔE value) between the single jersey and rib knitted fabric was found to be **2.081** (greater than 1), indicating there is a perceivable color difference between these two samples.

Color fastness evaluation

As can be seen in Tables 1–3, different shades of red tones with good to excellent color fastness properties (washing, rubbing and artificial day light) were obtained. All samples have good to excellent (4-4/5) washing fastness, indicating that there is no perceived color change and staining on adjacent fabrics (Table 2).

Table 3 indicates that the samples have excellent dry rubbing fastness (4/5), good wet rubbing fastness (4) and excellent light fastness gray scale rating (4/5).

Table 1 Color measurement results

Sample codes	CIEL*a*b* ve Tristimulus values								
	L*	a*	b*	C*	ho	X	Y	Z	ΔE
Rib	72.74	12.1	11.82	16.91	44.34	46.61	44.78	37.76	-
Single jersey	74.63	11.38	11.3	16.03	44.8	49.28	47.69	40.86	2.081
Interlock	83.6	9.04	10.68	13.99	49.76	63.89	63.31	56.04	11.339

Table 2 Color fastness to washing

	Color change	Color staining					
Color fastness to washing		Acetate	Cotton	Nylon	Polyester	Acrylic	Wool
Interlock	4/5	4/5	4/5	4	4/5	4/5	4/5
Single jersey	4/5	4	4/5	4	4/5	4	4/5
Rib	4/5	4	4/5	4	4	4	4/5

Table 3 Color fastness to rubbing and artificial light of dyed samples

	Color fastness to rubbing		Color fastness to artificial light
	Dry	Wet	
Interlock	4/5	4	4/5
Single jersey	4/5	4	4/5
Rib	4/5	4	4/5

Conclusion

In this study, the dyeing properties of knitted cotton fabrics with three different constructions using Indian madder, a natural dye, were examined and the effect of the knitting structure on dyeing ability was evaluated.

It was observed that all three fabrics had different tones of reddish colors with excellent to good color fastness properties. However, depending on the tightness of the structure of the fabric, the greatest differences in color values (CIE L*,a*, b*, C*, h^0, ΔE) were observed in the interlock fabric when other parameters were kept constant. It is expected that this study will contribute to the literature and highlight the importance of the use of natural dyes in textile dyeing.

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Conflicts of interest

Authors declare that there is no conflict of interest.

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