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Eco-Friendly Dyeing of Tencel Fabric by Using Natural Dye Extracted from Eucalyptus Leaves

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ABSTRACT The usage of natural dyes as environmentally suitable dyeing methods has extended during the recent years. The prime focus of this research is on the extraction and purification of natural dyes from eucalyptus leaves. With its numerous applications, eucalyptus leaves are highly valued for their diverse application, particularly as a rich source of natural colours. Quercetin is the primary colouring component in eucalyptus leaves. It has been utilized as a food dye with strong antioxidant properties and as an antioxidant. The goal of this research is to dye Tencel fabric using eucalyptus leaf-derived natural dye. The dye was extracted by using an ultrasonic extraction technique. Different ratios of the two mordants copper sulfate and ferrous sulphate were applied. Dyeing was carried out with different temperatures and concentrations and the pre-mordanting method was used for mordanting. The dyed Tencel fabric displayed a good colour strength of (K/S = 4.72), CIELAB values, and good to excellent light fastness (5), wash (4-5), perspiration (4-5), and rubbing (dry and wet = 4-5) fastness properties.

INDEX TERMS color fastness, extraction, eucalyptus leaves, natural dyes, quercetin, Tencel

I. INTRODUCTION

The non-biodegradables waste released from the leather and textile industries has key role in the water pollution of the world. The aquatic ecosystems are seriously anxious by water pollution due to hindrances in photosynthesis and carcinogenicity [1]. This increasing problem for the

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environment and aquatic system has attracted the attention of researchers to find a friendly product, which can be used as a colour pigment in different textile industries during the dyeing process. Dyeing is an ancient art, which precedes written records [2]. It has been studied since the Bronze Age. These dyes may provide a wide range of appealing colours with sufficient degrees of colorfastness, which are characteristically eco-friendly [3]. Although synthetic dyes are widely and economically used to provide uniform colours to textile fibers and fabrics, however, they are extremely poisonous; impair benthic photosynthesis, and carcinogenic [4]. Many nations forbid the use of certain azo dyes (-N=N-) in their manufacturing and use [5]. After this ban, people have moved towards natural dyes because of natural products, which are especially obtained from plants and have gained attractiveness globally for their use in textiles due to their availability, minimal toxicity, environmentally favourable outlook, biocompatibility, and green nature [6].

The term natural dye refers to all dyes, which are obtained from organic materials like plants, minerals, and animals. The colourants used in natural dyes are those produced from plant and animal substances without the use of chemicals. Roots, leaves, flowers, bark, and fruits of plants all contain colouring compounds [7].

Natural dyes are fully biodegradable and non-toxic, so it does not create any environmental issues [8]. Natural dyes have also anti-allergic and deodorizing properties because they have an environmental friendly nature. Natural dyes are in high demand because they are created and utilized without the use of strong acids or alkalis [9]. Natural dyes have been used since prehistoric times to produce different colours for yarns, fabrics, foods, and leather. [10]. It has many benefits it can provide subtle, shiny, and soft colours to the brightest colour to the yarn and fabrics and they can also provide a large amount of beautiful shades with acceptable levels of colorfastness, which can be easily available and renewable [11]. Additionally, natural dyes have certain drawbacks, such as low colour yield, inconsistent results, difficulty during the dying process, mixing issues, and poor fastness characteristics [12]. Mordants are chemicals, used to solve poor fastness issues. Natural dye has very little affinity for fibers and fabrics and very poor fastness capabilities when employed without mordants. A mordant is a substance that causes a chemical reaction to occur between the dye and the fibers [13].

Eucalyptus is a plant, which is produced in marshland, valleys, and mountains. Its trees have leathery, white leaves, which usually have an odd fragrance [14]. Eucalyptus bark is one of the most significant sources of yellowish-brown dye [15]. Eucalyptus colouring material contains a lot of polyphenols and natural tannins, ranging from 10%-12%. The primary antioxidant and colouring ingredient in eucalyptus is quercetin. The substance has been used as an efficient antioxidant in food colouring [16]. Eucalyptus leaves contain up to 11% of the principal tannins (gallic acid and ellagic acid), as well as lower amounts of flavonoids (quercetin and rutin) [17]. Tannins and flavonoids are considered especially helpful dye-fixing agents due to their ability to maintain colours within fabrics [18]. Figure 1 shows the composition of the main colouring compounds contained in eucalyptus leaves. In this work, Tencel fabric is dyed by using an extracted dye from Eucalyptus leaves. The efficacy of using excellency on the tencel fabric was evaluated using two mordants, copper, and ferrous sulphate. Eucalyptus leaves dyes were extracted by using the ultrasonic extraction process, and tencel fabric's colour strength, washing, light, rubbing, and perspiration fastness qualities were examined by using the pre-mordanting method.

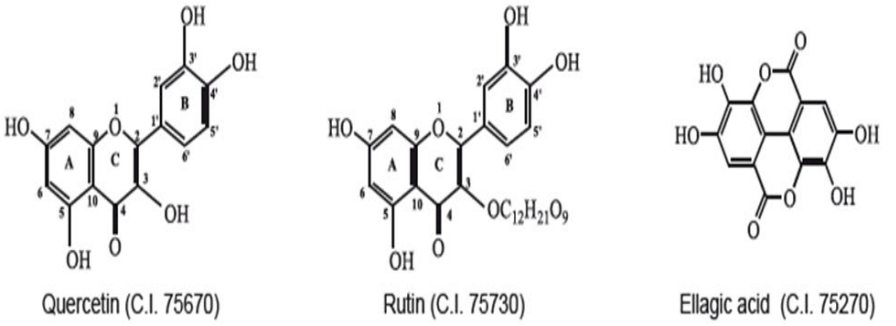


FIGURE 1. Colour materials of Eucalyptus leaves dye

II. MATERIALS AND METHODS

The leaves of eucalyptus shown in Figure 2 were bought from a store in Songjiang, Shanghai, China. A 100% Tencel fabric (warp-30, weft-30, plain weave, fabric density 128 × 82, fabric weight 155 g/m^2,) was bought from Hangzhou Xinsheng Printing and Dyeing Company LTD, which was utilized for dyeing. Sonicator was employed to extract the dye. Using a water shaker-dyeing machine for the mordanting and dyeing process. Two

laboratory-grade metallic salts, ferrous (II) sulphate, coppers (II) sulphate made by Sinopharm Chemical Reagent, CO.LTD, were employed as chemical mordants and ethanol was used as a solvent.

FIGURE 2. Eucalyptus Leaves

A. POWDER PREPARATION

Eucalyptus leaves were collected from local market in songjiang shanghai and then rinsed with distilled water to get rid of the pollutants and dust particles. The cleaned leaves were left to dry for 48 hours in the sun or at the room temperature. The sample were ground into powder with a grinder after drying process and passed through a sieve 20 mashes to get leaves powder with a constant particle size. Furthermore, the powder was used for the extraction process. Figure 3 shows the powder of eucalyptus leaves.

FIGURE 3. Eucalyptus leaves powder

B. DYE EXTRACTION

The dye was extracted from eucalyptus leaves using the ultrasonic extraction technique. An amount of 15 g of eucalyptus leaf powder and 450 milliliters of solvent (270 ml of ethanol and 180 ml of distilled water) were combined in a beaker at a 1:30 ratio. Hence, by using a frequency of 27–30 MHz and a supply voltage of 160 volts, the beaker was put in an ultrasonic bath and sonicated for one hour at 60°C. The Whatman filter paper was used to filter the solutions and a rotary evaporator was used to evaporate the solvents.

C. MORDANTING AND DYEING

Mordanting is a process, which produces a chemical reaction between fibers and dye that increases the dye uptake properties of the fabric. Accurately, Tencel fabric was treated with different chemical concentrations copper and ferrous sulphate. At 90°C temperature, the mordanting was carried out for an hour. Pre-mordanting was done by using a 1:30 liquor-to-water ratio. By following the mordanting procedure, the samples were taken out, pressed, and then dried at the room temperature.

This sample was then utilized in the dyeing process.

Hence, by following the mordanting procedure, dyeing would be done to give colour to the textile material. Thereby, using an exhaust technique, different eucalyptus extract dye concentrations were used to colour Tencel cloth. The Tencel fabric was dyed in a water shaker-dyeing machine for 1 hour at a material-to liquor ratio (M.L.R.) of 1:30. Tencel fabric was dyed at 80°C and 90°C temperatures to test the impact of temperature on dyeing. Following the dying procedure, the fabric was washed in cold water with soap before being dried in an oven or at room temperature.

TABLE I

MORDANTING AND DYEING RECIPE PARAMETERS

Process	Samples (g)	Solution	Temp	Time(min)	L:R
Mordanting	4	7% owf	90°C	60	1:30
Dyeing	4	10% dye	80°C, 90°C	60	1:30

D. EVALUATION OF COLORFASTNESS AND STRENGTH CHARACTERISTICS

To examine various qualities of the dyed samples, an evaluation was conducted to investigate their characterization. The dyed sample's colour strength (K/S) and CIELAB values were evaluated using the Spectra Flash-Data Colour, SF-600.

The dyed samples underwent tests for color fastness against light (ISO 105-B02), washing (ISO 105-C06), rubbing (dry and wet) (ISO 105-X12), and perspiration (ISO 105-E04) in accordance with ISO standards.

III. RESULTS AND DISCUSSIONS

In this experiment work, Tencel fabric was dyed by using eucalyptus leaves and two types of chemicals, namely ferrous and copper sulphate at 80°C and 90°C temp. by using various mordanting chemicals and by analyzing various fastness qualities. Hence, it is possible to achieve several shades and colours with the same natural dye. Pre-mordanting is employed as a mordanting technique in this research to use eucalyptus leaves as an eco-friendly natural dye.

A. DYE ABSORPTION AND COLOUR MEASUREMENT

The concentration of dye absorption on the surface of Tencel fabric is determined by using the K/S values on the Spectra Flash-Data Colour, SF-600. Values of L*, a*, b*, C*, and h* are used to measure the spectrum of colours, which are present in Tencel fabric. Figure 4 displays the K/S values of dyed tencel fabric with chemicals, namely ferrous and copper sulphate at 80°C and 90°C temp. because it had superior coordination complexes between dye and fibre. Therefore, the maximum K/S value (4.72), was found at temperature 90°C with ferrous sulphate. The K/S readings showed higher values at both temperatures than copper sulphate when dyed Tencel was mordanted with ferrous sulphate. As the concentration of the mordanting agent rises, the value of colour strength. Table II lists the L*, a*, b*, C*, and h* values, as well as, the colour shade of the fabric. Moreover, the table shows that for Tencel, lower values of L* correlate to the darker hues and higher values of L*, which correspond to the lighter shades, whereas negative values of a* and b* correspond to the colors green and blue. Due to the chemical mordants, copper sulphate had the lowest colour value (K/S = 2.31), while ferrous sulphate (K/S = 4.72) has the greatest colour value.

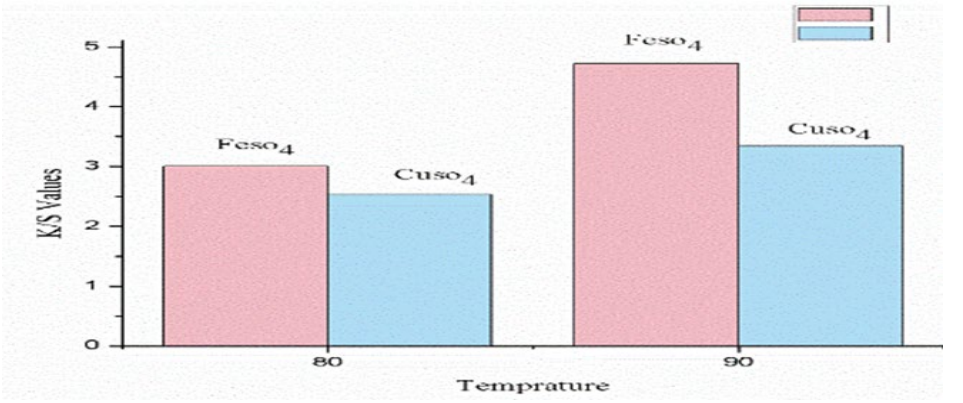


FIGURE 4. K/S values of Tencel fabric with temperature 80˚C and 90˚C

B. COLOR FASTNESS PROPERTIES OF DYED TENCEL

Eucalyptus leaves are well known for excellent dyeing results in fabrics with exceptional color fastness (Light. Wash) properties.

C. LIGHT FASTNESS

In color fastness to light, the tencel fabric was dyed with Eucalyptus leaves by using mordants, namely ferrous sulphate and copper sulphate. Ferrous sulphate was identified to improve light fastness because the sample exhibits no colour fading or change. As indicated in Figure 5, dyed tencel fabric exhibits excellent light fastness (grade = 4-5) on mordant ferrous sulphate and good light fastness (grade = 4) on mordant copper sulphate.

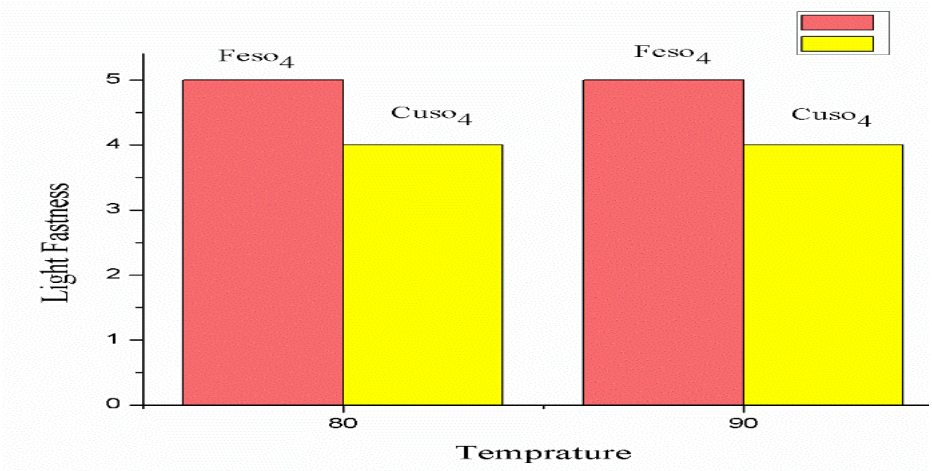
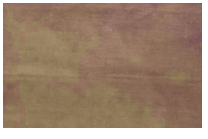
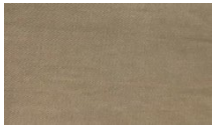


FIGURE 5. Light fastness Tencel fabric

TABLE II

VALUES OF CIE L* A* B* C* H* AND K/S

Mordant	Temp	K/S	L*	a*	b*	C*	h*	Raw Materials	Fabric Shade
Ferrous Sulphate	80	3.07	54.51	0.84	3.46	3.56	76.42		
	90	4.72	44.99	0.55	1.10	1.23	63.41		
Copper Sulphate	80	2.31	78.56	7.10	22.21	23.31	72.28		
	90	2.96	74.63	6.57	21.52	22.50	73.01		

D. WASHING FASTNESS

Tencel fabric is dyed with Eucalyptus leaves using ferrous and copper sulphates as a mordant to increase the washing fastness. The chemical ferrous sulphate exhibits good to exceptional fastness (4-5) for washing at 90°C, as well as, good fastness (4) for washing at 80°C, as indicated Figure 6. Reportedly, on both temperatures, mordant copper sulphate provided extremely good (4) fastness.

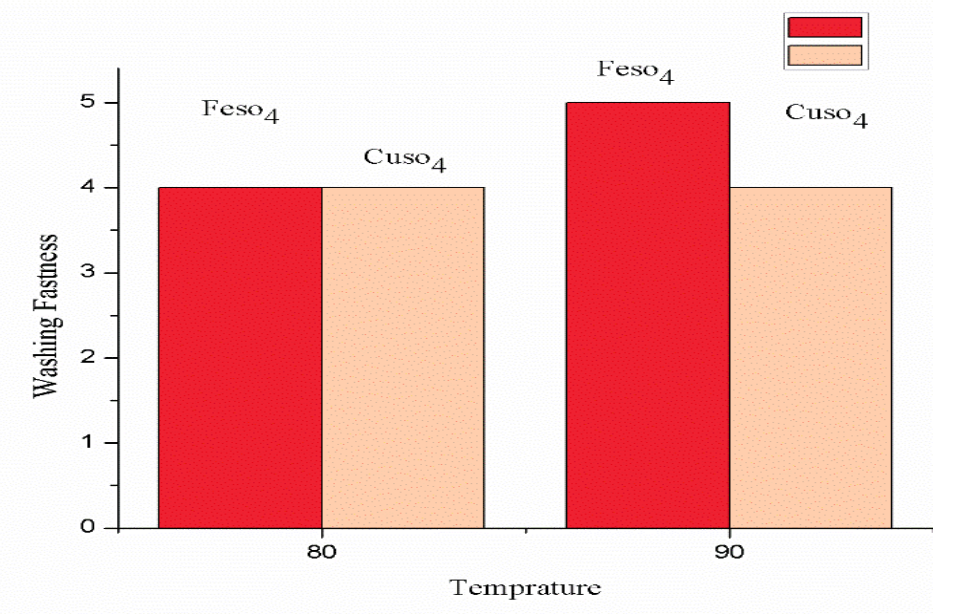


FIGURE 6. Washing fastness of Tencel fabric

E. DRY AND WET RUBBING FASTNESS

Figure 7 clearly indicates that rubbing on tencel fabric with eucalyptus leaves has excellent effects for fastness. Chemical ferrous sulphate was found to exhibit good to exceptional (4-5) dry rubbing fastness on both temperatures (80 and 90°C) and good (4) wet rubbing fastness on both temperatures. On both temperatures copper sulphate exhibited good (4) dry and wet rubbing properties. Overall, it can be said that dry rubbing was noticeably superior to moist rubbing.

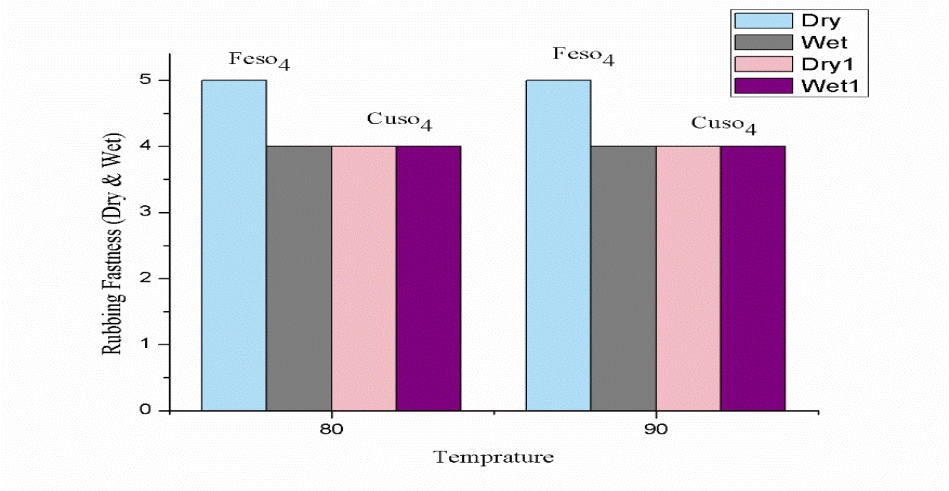


FIGURE 7. Rubbing fastness values of Tencel fabric

F. PERSPIRATION FASTNESS

It is clear from Fig. 8 and 9 that tencel fabric coloured with eucalyptus leaves exhibits a good perspiration fastness. The figures finding demonstrated very well to outstanding (4-5) fastness for both chemicals, namely ferrous and copper sulphate on both temperature for acidic and alkaline perspiration.

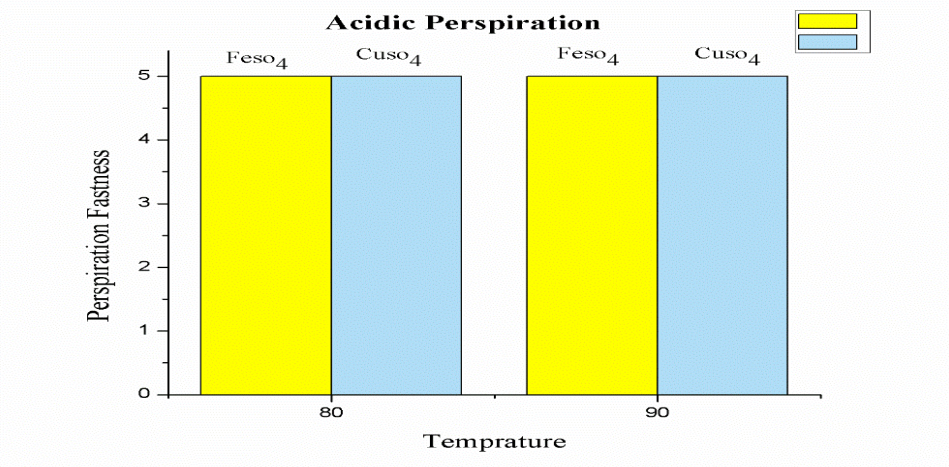


FIGURE 8. Acidic perspiration result of dyed Tencel

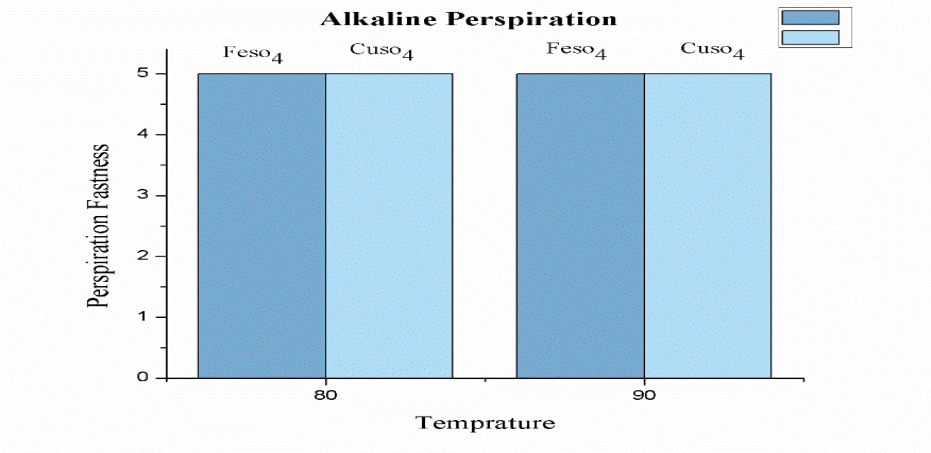


FIGURE 9. Alkaline perspiration result of dyed Tencel

TABLE III

COMPLETE RESULTS OF COLOR FASTNESS VALUES

Chemicals	Temp	Washing Fastness	Light Fastness	Rubbing Fastness		Perspiration Fastness	
				Dry	Wet	Acidic	Alkali
Ferrous Sulphate ($FeSO_4$)	80	4	4-5	4	4	4-5	4-5
	90	4-5	4	4-5	4	4-5	4-5
Copper Sulphate ($CuSO_4$)	80	4	4-5	4	4	4-5	4-5
	90	4	4	4-5	4	4-5	4-5

G. CONCLUSION

The current study as a potential source of synthetic dye suggested that the eco-friendly dye derived from eucalyptus leaves can be used as natural dye. the dye derived from eucalyptus leaves can be used. Therefore, an organized study of extraction, testing, and improving properties of dye is necessary to reduce the cost asset, dye purity, and yield growth. Eucalyptus leaves dye is the dye, which give such useful properties. In this work, dye was extracted from Eucalyptus leaves, which is a natural plant that is applied to the Tencel fabric as a natural eco-friendly dye. For this purpose, two chemicals were employed as mordants, ferrous, and copper sulphate, which produced good effects. Noticeably, the entire process of extraction was naturally protected and the ultrasonic procedure was fast for a timesaving process. Tencel fabric was ideally used for dyeing because it contains many properties like, high

absorbency, strength, antibacterial property, and fully biodegradable. Tencel fabric stained with eucalyptus leaf dye offers a good colour strength of (4.72), colour fastness to washing from (4-5), light ranging from (4-5), rubbing (4-5), and perspiration (4-5), among other significant qualities. However, there is a requirement for appropriate information, documentation, and evaluation of color-yielding plants and the diminishing procedures in order to build the utilization of natural dyes.

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