Wash Fastness of Textile Fibers Dyed with Natural Dye from Eucalyptus Wood Steaming Waste

Ticiane Rossi, Maurício C. Araújo, José O. Brito, Harold S. Freeman

***Abstract*—**Natural dyes are gaining interest due their expected low risk to human health and to the environment. In this study, the wash fastness of a natural coloring matter from the liquid waste produced in the steam treatment of eucalyptus wood in textile fabrics was investigated. Specifically, eucalyptus wood extract was used to dye cotton, nylon and wool in an exhaust dyeing process without the addition of the traditional mordanting agents and then submitted to wash fastness analysis. The resulting dyed fabrics were evaluated for color fastness. It was found that wash fastness of dyed fabrics was very good to cotton and excellent to nylon and wool.

***Keywords*—**Eucalyptus, natural dye, textile fibers, wash fastness.

I. Introduction

THERE is a movement in our society towards sustainability, green and environmentally friendly products, as well as specific market niches [1], [2] that has led to the consideration of wood industry as potential places to find sources of natural dyes for textiles [3], [4]. This interest has been intensified by consumers worldwide that have higher ecological awareness and are more demanding about including this perspective in product development along the supply chain.

In order to reduce environmental problems, the textile industry has adopted strategies such as cleaner production in order to eliminate the use of toxic raw materials, increasing the efficiency of water use, and energy reduction in wastewater treatment [5]. As a result, the increased interest in natural materials and renewable resources has come to the forefront, which motivates the investigation of natural dyes.

Historically, the use of natural dyestuffs has been limited by technical properties required in the textile industry, including the ability to conduct dyeing process in existing equipment, reproducibility of fabric shades from batch to batch, and acceptable color fastness properties, i.e., the permanence of dyes under end-use conditions [1]. Among the procedures most often cited in the literature dyes in order to increase the fastness properties and the substantivity of natural dyes is the inclusion of mordents, which are transition metal salts, in the dyeing process [2]. However, nowadays, according with cleaner production processes required in textile industry, the reduction of the use of toxic substances, in general, is important. In this concept, the source of dyes it is also decisive to determine a sustainable product at the end of the chain.

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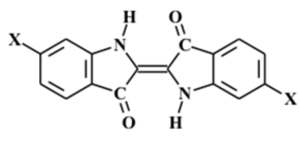
In an effort to find a source that can fulfill these requirements, the eucalyptus is an option studied, as a natural dye for textile dyeing [3], [4].

A. Natural Dyes

Generally, there are three types of natural dyes for dyeing textiles [6]:

1) Substantive dyes, which bond directly to textile fibers during the dyeing process without adding a mordant [7];
2) Traditional dyes, which characterize the majority of the natural dyes family. This group requires the formation of a mordant-fiber complex to establish a dye-fiber connection [8]–[10].
3) Vat dyes, which are treated with alkali and sodium hydrosulfite to become soluble and diffuse into the fiber [7]-[9].

Colorants from natural sources can be organized by their chemical structure, namely indigoid, as shown in Fig. 1, which occur as colorless precursors and are converted into purple to blue dyes through a fermentation and oxidation process [11], and anthraquinone dyes (Fig. 2), which comprise most natural red dyes obtained from plants and insects. Anthraquinone-based natural dyes include madder, kermes, cochineal and lac.



(X = H, Br)

Fig. 1 Representative molecular structure of natural dyes, indigoid

Other natural dye families are flavonoids and neoflavanoids (Fig. 3), which include fusic, brazilwood and logwood [8], [12]. The associated yellow colors are obtained from wood, flowers, and seeds, such as Persian berries, yellow wood, onion skin and flax leaved daphne [13], [14]. Dihydropyrans are structurally related to flavones [15]. They comprise the principal components of logwood, which is widely used to give dark shades on silk, wool and cotton.

Logwood extract contains two brown substances, mainly quercetin and tannin. The extract can be exposed to oxygen and alkali to produce red, blue and purple dyes [7], [11].

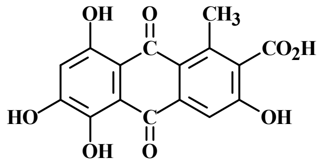


Fig. 2 Representative molecular structure of natural dyes, anthraquinone

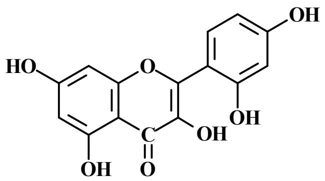


Fig. 3 Representative molecular structure of natural dyes, flavonoids

B. Wash Fastness of Natural Dyes

The fastness to wash (household wash/laundry) is one of the central properties used to characterize dye textile material [16].

The wash fastness is dependent of the methods of dyeing and application. Studies with natural dyes showed that there are some distinctions of colors after washing the dyed textiles in the alkali presence, which emphasizes the need of knowing the pH of alkali solutions to clean natural dyed garments [17].

In terms of fibers, fastness properties of natural dyes on cotton are generally quite low. Consequently, they have largely been replaced by synthetic dyes that are more cost effective, brighter, and more durable under end-use applications [18].

C. Eucalyptus Wood Steaming Waste

A promising concept for obtaining natural dyes with low specific cost involves the use of different sources to natural extracts: i) directly produced by the producer are very expensive, but available elsewhere; ii) use of cheap by-product of other agricultural and forestry activities, for example, wood bark or leaves industry abundantly available, such as eucalyptus; iii) use of dyes contained in waste, that is released from the food industry and drink without cost [19].

The eucalyptus is a widely cultivated plant in Brazil, whose acreage currently is about 4.75 million hectares spread over almost of its states. It is estimated that there are approximately 600 sawmills dedicated to processing its timber, which comprised 9.0 million tons of lumber in 2010 and reflected an average annual growth rate of 1.7% [6].

Studies of natural dyes from wood and leaves from eucalyptus had good results in terms of wash fastness properties [3], [4].

Besides the use of the eucalyptus wood and leaves as sources for natural dyes, the use of waste of industrial wood processes is also an opportunity. One example was the use of eucalyptus extract waste from the leaves, generated during the process of essential oil production. The study evaluated the waste as a natural colorant for dyeing cotton, and demonstrated the feasible to obtain a final product that presented good wash fastness rates, without using any mordent agent. The brown aqueous extract gave light brown shades on cotton. The rate on wash fastness was 3-4 for dyebath concentration of 10% based on the fabric weight (owf). The multifiber fabric staining ratings were greater than 4 [20].

This early success motivated the sequence of studies considering the dye waste effluent from industrial steaming eucalyptus wood as a raw material for dyeing textile fibers. The process of steaming eucalyptus wood includes to treat the lumber to steam at 90°C in a closed chamber during 36 hours. The water in the treatment tank becomes dark brown, providing the colored waste used for dyeing textiles in this study. The objective of this work was to evaluate the wash fastness of the final textile product after dyeing with the eucalyptus wood steaming waste.

The possibility of using such waste from steaming eucalyptus wood could add value to the source, the eucalyptus wood, as well as the processing itself. Instead of being discarded without defined use, the waste would be recovered as a by-product to another application. In this sense, the industry could reduce the step of waste treatment; with means reduce of costs of processing.

From the point of view of industry, using the waste as a natural dye frames an innovative final product. It can be also an eco-friendly alternative in regard of synthetic dyes, focusing on specific market niches such as organic fibers and garments and certified products. This is consistent with the trend of the Brazilian textile fashion that, in general, points to the need of developing niche markets in the sense of differentiation and increased value in garments [21]. Accordingly, dyeing fabrics using natural dyes from the steaming eucalyptus wood process could be seen as a differentiation factor to the final product.

In terms of fashion and color chart can be said that colors obtained from natural dyes are soft and pleasing the human eye, and are quite consistent with the current fashion [10].

It is worth noting, a product of natural origin, the treatment of wastewater generated by the dyeing with eucalyptus waste could be done by biodegradation [10], [20]. Furthermore, in terms of toxicity, eucalyptus extract could be an alternative to replace more toxic synthetic dyes, carcinogenic and allergenic [4], [18].

II. Experiments

A. Material

Eucalyptus liquid waste from lumber steaming was supplied by Depinus, a company located in the city of Curiuva, Paraná State, Brazil. The timber subjected to steaming was *Eucalyptus grandis* Hill Ex. Maiden. The characteristics of the liquid indicated a pH value of 5.1, a dark brown coloration, 2.2% of total solids contents and with 0.9% of condensed tannins [6].

B. Textile Dyeing

Textile dyeing employing the liquid waste was carried out in the Textile Laboratory at the Escola de Artes, Ciências e

Humanidades, using an HT Mathis machine for exhaustion dyeing. The knitted fabrics used were cotton 98% with 2% of elastane, nylon 6-6, and fabric 100% wool, all prepared for dyeing.

The exhaustion dyeing method was used (Fig. 4). There was not addition of metal salts, and the dye concentrations used 1, 10 and 20% based on the fabric weight. Dye bath contained NaCl at the concentration of 20 g/L and the liquor ratio was 10:1 [6], [22].

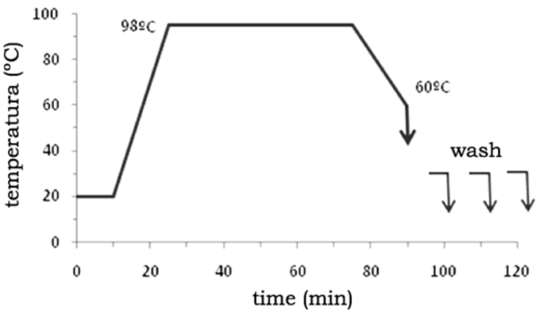


Fig. 4 Exhaustion dyeing method [6]

The mass of extract waste was added to the dye bath according to (1) [6], in wich "mw" was the mass of eucalyptus waste in grams; "cw" was the waste concentration to be applied, in percent; "mf" was the fabric mass and "cts" was the content of total solids:

$$mw = (cw \times mf)/cts \tag{1}$$

After dyeing, the fabrics were washed with a solution of 1 g/L of neutral detergent in distilled water during 10 minutes at 30ºC. After this, the fabrics were washed in running water and dried at low temperature for 30 minutes. Two repetitions were performed for each fabric in each dye concentration.

C. Color Assessments

Colorimetric analysis was used to measure the L*a*b* values. The operating conditions of the equipment included scanning from 360 to 700 nm, CIE illuminant D65, and observer angle of 10º.

L*a*b* values were analyzed by Analysis of Variance (ANOVA) with 95% confidence interval, followed by multiple comparisons among means (Tukey's tests).

The color strength and color depth of dyed samples were determined by light reflectance technique using a Hunter Lab spectrophotometer Color Quest XE. The color strength (K/S) value of samples was evaluated using the "Kubelka-Munk equation", according to (2) where R is the reflectance of the dyed sample; K is the absorption coefficient and S is the scattering coefficient [23].

$$K/S = (1-R)^2/(2 \times R) \tag{2}$$

D. Wash Fastness Properties

The color fastness to washing of dyed samples was determined based on the standard the method A1S from ABNT NBR ISO 105 C06 [6] at the laboratory of Golden Química industry, in São José dos Campos, São Paulo, Brazil. The difference obtained between the control fabric and the multi-fiber, before and after washing, was visually compared with the gray scale to obtain the color change and the staining.

III. Results and Discussion

The results of L*a*b* of dyed cotton, nylon and wool are shown in Table I. The K/S values in each dyed fabric for each dye concentration is shown in Fig. 5. Wash fastness properties are shown in Table II.

TABLE I
COLOR VALUES OF DYED FABRIC

Fabric	Dye Concentration (%)	Color Co-ordinates L*	a*	b*	Color Obtained
	1				yellowish
Cotton	10	62.80	7.76	14.33	yellowish
	20				yellowish
	1				brownish
Nylon	10	59.09	8.26	16.41	brownish
	20				brownish
	1				brown
Wool	10	48.92	12.47	19.32	brown
	20				brown

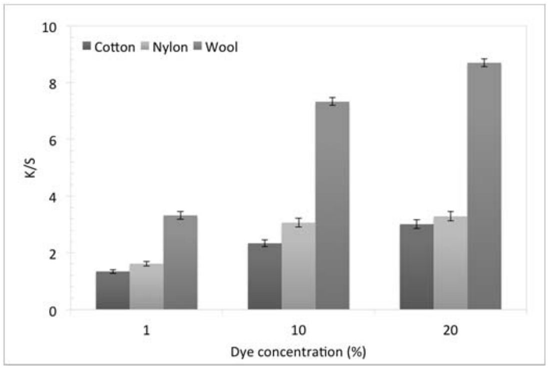


Fig. 5 K/S values in each dyed fabric of cotton, nylon and wool for each dye concentration

The dyed fabrics had yellowish and brown shades. The neutral colors are coherent with the fashion today [10].

The L*a*b* results indicated that the eucalyptus extract had more affinity for wool than nylon and cotton, probably due to the inherent ionic character of wool. Tannins can bind protein [24]. The used waste is composed of tannins, and this explains the higher affinity for wool, a protein fiber.

Fig. 5 can also show the same behavior. The wool dyed samples presented the greater K/S values in all dye concentrations, from 3.3 to 8.7. Nylon dyed knits presented the intermediary K/S values in comparison with wool and cotton, from 1.6 to 3.2 for the dye concentrations studied. Cotton, with the lower values presented 1.3 to 3.1 K/S values.

Regarding the dyeing process, the eucalyptus waste could be classified as a substantive dye [7], because it binds directly with the textile fibers without the use of any mordant in the dyeing process.

TABLE II
WASH FASTNESS RESULTS

Fabric	Dye Concentrations (%)	Colour Change*	Colour staining of adjacent fibers [a]					
			Acetate	Cotton	Nylon	Polyester	Acrylic	Wool
Cotton	1	4	5	5	5	5	5	4-5
	10	3	5	4-5	4-5	5	5	5
	20	3	5	5	4-5	5	5	4-5
Nylon	1	3	5	5	5	5	5	5
	10	4-5	5	4-5	5	5	5	5
	20	4-5	5	4-5	5	5	5	5
Wool	1	5	5	5	5	5	5	5
	10	4-5	5	4-5	5	5	5	4-5
	20	4-5	5	5	5	5	5	4-5

[a] Rates from 5-1, excellent to poor, respectively

The results of wash fastness indicate that color change from fabric washing reflected excellent ratings on nylon and wool, 4.5. Color changes in cotton are considered acceptable, with rate 3. In terms of staining, the ratings were >4.5 for all the fibers, showing excellent fastness to staining. The results indicated that fastness levels for the dyeings obtained from eucalyptus were suitable for cotton, nylon and wool fabrics.

The characteristic of eucalyptus extract as a colorant indicates finals uses as lingerie and men's underwear, because of the shades obtained in the fabrics, such yellowish, brown and beige. Such shades are frequently present in color charts of all collections of all brands, being a basic color of this segment. For these final uses, light fastness is not important, while wash fastness is important.

IV. CONCLUSION

Dye fabric with waste from steaming eucalyptus waste was possible without the use of mordanting agents, resulting in yellowish, brownish and brown colors. There were found excellent ratings on wash fastness in nylon and wool fabrics, and very good rates on cotton. The results indicated that the liquid waste product from steaming eucalyptus wood is a potential source of natural dye for dyeing cotton, nylon and wool fibers.

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