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Study of the feasibility of a natural dye on cellulosic textile supports by red padouk (*Pterocarpus soyauxii*) and yellow movingui (*Distemonanthus benthamianus*) extracts

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ABSTRACT

Alkaline and aqueous extractions of padouk and movingui sawdust were performed in this study with the aim of using to dye cotton fabric, wood viscose and bamboo viscose textiles. Coloration was carried out without a mordant. Colored materials were washed with soap and the extent of staining was measured fifteen days later using a Datacolor D65°10 apparatus. The parameters L^*, a^*, b^* were measured to determine the depth of the color penetration after dyeing. A comparison of the different cellulosic supports showed that cotton presents generally a better ability to dyeing than bamboo and wood viscose.

1. Introduction

Textile industries produce a lot of waste water which contains a number of pollutants, including caustic or acidic components, toxic contaminants and different dyes. Most of dyes used in textile finishing are synthetic and derived from petrochemicals. These organic compounds are hazardous, can cause skin allergies and cancer diseases and can release toxic and harmful by-products during their synthesis (Mohammad et al., 2011; Moiz et al., 2010). As a consequence, during the last decade, there has been a revival of interest in the use of natural colorants in textile dyeing. Moreover, as a response to current allergic and toxic reactions related to synthetic dyes, many countries have imposed stringent environmental standards. Thus, there is an increasing interest for the production of natural dyes from plant renewable resources. By-products from agriculture and forestry appear therefore as valuable starting material to convert unwanted wastes into value-added useful dyes. Colorants extracted from these materials, of which billions of kilograms are produced annually, are explored as new sources in coloring wine, food and animal, plant or synthetic fibers.

Situated in Central Africa, Cameroon has an extensive equatorial forest which represents almost 22 million hectares (about 42% of the national country area), with almost 300 wood species. The timber industry in Cameroun generates large amounts of waste, some of it is used as fuel, and the other abandoned. The valorization of waste is a challenge for sustainable development of the local economy and industrial processes. Some tropical wood species have high extractives contents in the heartwood (Saha Tchinda et al., 2013). These extractives influence the color, odor, durability and technological properties of the different wood species (Shiraishi, 1991). In Africa in general and Cameroon in particular, some wood species have strongly colored extracts which can be used as natural dye in the textile industry. Eco-mark natural dyes are non-toxic, non-allergic, and completely safe for the skin and environmentally friendly colorants currently sold on the market. Their stability can be achieved by using an appropriate mordant. Extracts of *Pterocarpus osun* were used in Nigeria as a natural dye to color collagen fibers (Avwioro et al., 2005; Akinloye et al., 2010). Many colored

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wood species in Cameroon can offer different colorants: red from padouk (*Pterocarpus soyauxii*) and yellow from movingui (*Distemonanthus benthamianus*) could be cited as examples. This study is devoted to the use of colorants extracted from these species as natural dyes to color classical textile materials.

Extracts of padouk mixed with a tin mordant were used in England in the 19th century to obtain an intense red color on clothes. The heartwood is a source of dye. In Africa, especially in Cameroon, the dye is used locally to dye fibers and cloths red. More recently, studies have shown that padouk contains various compounds such as biflavonoids (santalin A, santarubins A and B), isoflavonoids (pterocarpin, formononetin and prunetin), isoflavone, quinone (claussequinone), isoflavanes (vestitol and mucronulatol), tannins, ascorbic acid, glucosides, triterpenes, xanthones, flavanoid (homopterocarpin), phenylpropen (anethol), pterosonins A–F (Betti, 2004; Surowiec et al., 2004; Tchamadeu et al., 2011; Saha Tchinda et al., 2013, Su et al., 2013). Moreover, high amounts of tannins contained in padouk could also contribute as mordant during the coloring process.

Movingui is a yellowish wood with traces of brown or green. The stem bark can be used in pharmacopeia to treat different bacterial, fungal and viral infections (Ngulefack et al., 2005). The bark of movingui tree is also used to treat rheumatism (Akendengué and Louis, 1994). Previous studies show that movingui contains flavonoids such as oxyayanin A, oxyayanin B, ayanin and distemonanthin used for their anti-tumor, antibacterial activity and in fighting dermatitis (Aiyegoro et al., 2008; Adeniyi et al., 2011).

The purpose of this work was to evaluate *in vitro* the dye characteristics of yellow movingui extracts and red padouk extracts with a view to assessing the coloration value of the extractives. Moreover this work aims to determine if movingui and padouk extracts can be used as colorants in order to valorize such wood industrial wastes.

2. Materials and methods

2.1. Chemicals and reagents

Distilled water and sodium hydroxide (with 99% purity purchased from Riedel de Haën Sigma Aldrich) were used for extraction.

2.2. Raw materials

Industrial boards of movingui and padouk were collected from the Société Industrielle de Mbang (S.I.M, Cameroon, Yaounde town). It should be noted that wood for industrial applications is harvested at different seasons and the moisture contents of considered species change. This was taken into account in the exploitation of results. Samples were air-dried in the laboratory to stable mass. The wood was ground using a Retsch SM 100 cutting mill and then sieved. Particle fractions of size between 0.2 and 0.4 mm were used to extract respective dyes.

2.3. Extraction of dye

Definite amount of sawdust were extracted with distilled water and aqueous solutions of sodium hydroxide of concentrations ranging from 0.05 M to 0.5 M at a solid to liquor ratio (M:L) of 1:10. The extractions were carried out for 1 h at 90 °C under atmospheric pressure in a stirred glass beaker sealed with parafilm wax. Solid particles were removed by filtration and the liquor was used to dye different materials. Extraction parameters (90 °C for 1 h) were chosen with reference to literature (Shaukat et al., 2009; Bechtold et al., 2007; Harivaindaran and Rebecca, 2008; Sivakumar et al., 2011).

Table 1
extractive amounts (%).

	Wood species	
	Movingui	Padouk
Amount of extractives with water	3.8 ± 0.1	4.0 ± 0.1
Amount of extractives with NaOH (0.05 M)	3.6 ± 0.2	4.3 ± 0.1
Amount of extractives with NaOH (0.1 M)	4.0 ± 0.1	4.5 ± 0.3
Amount of extractives with NaOH (0.2 M)	4.4 ± 0.1	4.7 ± 0.2
Amount of extractives with NaOH (0.3 M)	4.3 ± 0.2	4.6 ± 0.4
Amount of extractives with NaOH (0.4 M)	4.7 ± 0.1	5.0 ± 0.1
Amount of extractives with NaOH (0.5 M)	4.7 ± 0.1	5.1 ± 0.2

2.4. Determination of the amount of the extractives by indirect method

As was mentioned in the raw materials presentation, the moisture contents of padouk and movingui wood species were not the same. The moisture contents (an average of three trials; the quoted uncertainty is the standard deviation) were (22.9 ± 0.1)% in movingui sawdust and (8.5 ± 0.1)% for padouk sawdust. Raw sawdust was weighed (m_{wet}) and after drying in an oven at 103 °C for 24 h, sawdust was weighed again (m_{dry}). The moisture content was obtained using the formula:

$$\text{moisture content}\,(\%) = \frac{m_{wet} - m_{dry}}{m_{dry}} \times 100 \quad (1)$$

The mass of dry wood introduced in glass beaker then calculated:

$$m_1 = m_{introduced} \times (1 - \text{moisture content}\,(\%)) \quad (2)$$

where $m_{introduced}$ is the mass air dried wood introduced into glass beaker and m_1 is the oven-dry mass of wood introduced into the glass beaker.

After extraction with sodium hydroxide or water, extracted dyes were separated from the sawdust by filtration; sawdust was dried in oven at 103 °C for 24 h and then weighed (m_2). The amount of extractives (AE) was estimated using the equation:

$$AE = \frac{m_1 - m_2}{m_1} \times 100 \quad (3)$$

Samples were weighed using a Mettler PC440 balance (10^{-2} g precision). Experiments were carried out in triplicate in order to ensure the reproducibility of results. The average values and standard deviations are reported in Table 1.

2.5. Absorbance measurements

The extracts were diluted ten times with distilled water and the absorbances were read using a SHIMADDZU (UV-2550, UV-visible) spectrophotometer in a 10.00-mm quartz cell. The maximum adsorption wavelength of different extracts was determined.

2.6. Dyeing procedure

Cotton fabric, wood viscose and bamboo viscose were furnished by Textile Technical Center (CETELOR) in Epinal, France. Dyeing experiments were performed at 90 °C in sealed beakers and laboratory dyeing apparatus using typically 1 gram of textile material for 25 mL of liquor (ratio of 1:25). Textiles were immersed in the extract at 25 °C in the dyeing apparatus and maintained at this temperature for 30 min. The temperature was then raised to 90 °C for 1 h, time for the pigment to penetrate the material. At the end of the dyeing process, the bath was cooled down to 60 °C. The dye bath was then removed; the textile rinsed three times with warm water at 60 °C to remove unfixed dye and then dried.