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Extraction of natural dyes for textile dyeing from the by-products of the timber industry

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ABSTRACT

The timber industry releases considerable amount of wastes which contain natural dyes. Such wastes could serve as sources for the extraction of natural dyes for textile dyeing operations. The extraction of various shades of brown colours from the bark of woods meant for the timber industry is of interest. By-products such as barks of wood were collected from Abura (Bahia elolom) and Ghana obeche (Triplochiton scleroxylon). They were grounded into powder and extracted and test dyeing on cotton, nylon 66 and acrylic fabrics were performed. The extracts were applied as direct dyes and in the presence of copper Sulphate or iron (II) Sulphate, Tin (II) chloride and potassium dichromate as mordants. The results prove the potential of such waste as a source for dyestuff extraction. To obtain textile dyeing with acceptable fastness properties, however, rigorous selection of dyes and development of suited processes is required. A considerable number of brown natural dyes need further research to optimize the low level of fastness to light.

Key words: Timber industry, natural dyes, textile dyeing; fastness; natural and synthetic fibres.

INTRODUCTION

Natural dyeing has been used by humans for many purposes varying from the coloration of textiles, food and cosmetics in order to impart other functions to them. However, natural dyes became progressively replaced by the[1,2] emergent of synthetic dyes.

The future demand for more sustainable processes can be seen as a driving force for new strategies which could bring a revival of natural dyes in textile dyeing. However, the costs of such dyes have to be lowered considerably and the quality level of the dyeing needs substantial improvement[3,4].

There are many reasons why many people are now turning to natural dyes even though synthetic dyes are more convenient to purchase and dye with. Each plant provides an amazing diversity of shades. From one plant you may obtain between 5-15 varying colours and shades. These colours and shades are subtle and tend to harmonize with one another. The resulting fabrics or fibres are now original pieces - it is extremely difficult for anyone to duplicate exactly[5].

Also, there is the question of ecology as people become more aware of environmental factors, dyers are searching for alternatives. Natural dyes are seen as more eco-friendly as, unlike their synthetic counterparts, since they are all derived from nature[6,7]. The dye baths can be neutralized through the addition of either acid or alkaline solution and then poured down the sink or onto the garden.

In addition, worldwide efforts to promote the cultivation of natural dye plants and their technical application for natural dyeing have been made by some projects such as the Pris CA in Italy and the INDINK in the UK[8]. A more efficient production process of natural dyeing is being developed by them. Also the re-evaluation of ecology is a major trend for influencing colour. Naturally dyed fabrics can meet the current global greening movement[9]. In Nigeria, the timber industry releases considerable amounts of wastes containing extractable natural dyes. Thus, the huge amounts of by-products such as the barks of wood released from the timber industry could be an important sustainable source for extraction of natural dyes as colorants for textiles.

The work presented in this article focuses on the extraction of natural dyes from the barks of woods used in the timber industry. The article summarises an experimental evaluation of potential sources of natural dyes. Important aspects presented in this paper considered extraction of dyestuff, extraction time and determination of selected fastness properties (light fastness, wash fastness) as key properties for technical and commercial success. The study also tried to identify the effects of mordants on the colometric properties of the naturally and synthetic dyed fabrics.

EXPERIMENTAL

Materials

A scoured (100% cotton fabric) was used for the natural fibre. Nylon 66 (plain-weaved nylon 66 fabric having 3898 ends/in and 3307 picks/m) and acrylic fabrics were used for the synthetic dyeing.

Instruments

The Uv-visible spectra of the dye extracts were determined by a genesys IOS VL 200 series spectrophotometer. The melting point of the solid dye extracts were also carried out with the use of gallenkemp block melting point apparatus and are uncorrected. The infra-red spectra was determined by the Nicolet, Averser 300 series spectrophotometer.

Extraction of dye and purification

Samples of the relatively fresh wood barks were collected from two sawmills located at Sapele, Delta State, Nigeria. A weighed powdered amount of the plant bark was treated with ethanol in a beaker. In the standard procedure, the ratio mass of plant bark to volume of ethanol was set at 1:50 which means that 1.0g of plant bark was extracted with 50ml ethanol. The extraction was performed for two days at 65^{o}C. The solvent (ethanol) was evaporated from the solution and the solid extract was purified by recrystallization from dimethylformamide in the case of abura. TLC analysis showed one spot for the abura dye extract and two spots for the Ghana Obeche dye extract.

Dyeing

Dyeings were performed by an exhaustion method using a liquor ratio of 1:20. For 1.0g of goods, a dyebath volume of 20ml was applied. The dyeing experiments were performed in aluminium vessels at 100^{o}C dyeing temperature. 1.0g of scoured cotton, nylon 66 and acrylic fabrics were used. After dyeing, unfixed dyestuff was removed by soaping off using non-ionic detergent, rinsed with water and dried. The detailed dyeing procedure is given in the literature[10]

Mordanting

The mordants used were ferrous sulphate, copper' sulphate, potassium dichromate and tin(II) chloride. The required amounts of mordant was dissolved in warm water and stirred till a clear solution was obtained. In premordanting, the fabric was first treated with the metal salt solution and then dyed. In post mordanting, the fabric was first dyed and then treated with the metal salt solution.

Fastness Properties

Light fastness

Light fastness was determined using artificial illumination with a zenon arc light according to DIN 54004 and AATCC 107-1997 (Xenotest, Hanau, Germany) and was related to the standard scale of blue dyeings[11,12].

Wash fastness

The wash fastness of all the dyed samples was tested according to ISO washing test number 3[13]. As a result of the high alkali sensitivity of natural dyes, it is recommended that these textiles be washed with non-alkaline soap only. Hence, non-ionic soap was used in this procedure. The composite samples measuring 10 x 4cm, were washed with 5g/L lissapol N at 50°C for 45min in a launderometer. The change in colour of the treated test specimens and the degree of staining of the two adjacent undyed fabrics was evaluated using the standard grey scale (marks 1-5, 1= poor, 5 = excellent)[14].

RESULTS AND DISCUSSION

The results of the UV-visible spectra (Table 1) of the dye extracts show strong broad absorption curves in the range 380 – 800nm with λ_{max} 431 nm. This indicates that the area under the absorption curve, which is the true measure of tinctorial strength of a dye is large. The broad absorption curve is a characteristic typical of brown colours [15].

The infra-red spectra of the dye extracts (Table 1) showed broad bands at 3436cm^{-1} and 3442cm^{-1} indicating OH and possibly NH groups. There is absence of strong bands in the 1800-1650cm^{-1} regions which is indicative of the fact that there is no carbonyl group in the compounds. The band at 1630cm^{-1} suggests the presence of ethers (C-O-C). Band at 1072cm^{-1} suggests the presence of sulphur in the abura dye extract. The band at 2926cm^{-1} for the abura dye extract and at 2931cm^{-1} for the Ghana obeche dye extract are indicative of the presence of C-H stretching vibrations in aryl compounds[16,17]. The results of the meeting point determination of the dye extracts show that the compounds are very stable to heat.

Light and Wash fastness

Light-fastness was identified to be the major hint for a general introduction of all tested natural dyes. A light fastness of at least 2-3 was set as a lower limit, for positive selection; however, values of light-fastness of 2 perhaps could be increased by further research activities to exceed the lower limit of 2-3.

In many cases, light fastness of natural dyeings is strongly influenced by the type of mordant used. For the results shown in Tables 2, 3 and 4, significant improvement of light fastness is found when mordants were added. The light fastness gradings show that unmordanted samples gave very poor fastness to light. This agrees with other unmordanted natural dyes such as munjistin that had earlier been reported[18,19]. However, the dye extract from abura gave moderate fastness on cotton and acrylic fabrics. It was also observed, that mordanting generally improved light fastness but postmordanting was found to be much more effective.

The results of the wash fatness of the two colorants obtained (Tables 2, 3 and 4) also showed that mordanting in general enhanced wash fastness. Mordanting with tin (ii) chloride or iron (ii) sulphate also gave an improvement in wash fastness but not as high as those of copper sulphate and potassium dichromate as mordants.

Table 1: Dyestuff extraction and spectroscopic properties

Source	Physical state	Wavelength (nm)	IR (KBr)cm^{-1}	MP°C
Abura	Solid	431	3438(OH, NH) 1630 (C-O-C) 1072(S^{2-}) 581(Ar-ring)	>360°C
Ghana Obeche	Solid	431	3442(OH,NH) 2931(C-H) 1631 (C-O-C) 579 (Ar-ring)	>360°C

Effects of mordanting on colour

Mordating has been applied to improve colour fastness of naturally dyed fabrics. In addition it is well-known that colour characteristics of the fabrics may change after mordating[20]. Therefore, we observed the effects by investigating the samples dyed with two different colorants (dye extracts) without any mordants and other samples dyed with the same colorants to those above followed by mordanting before and after dyeing with one of copper, or iron, tin and chrome.

Abura dye extract

Unmandated, this type dye extract gave brown colour on cotton, nylon and acrylic fabrics. Postmording with potassium dichromate cause the colour to become deeper shade on acrylic fabric whereas premording with copper salt and tin (II)

Table 2: Fastness properties of dye extracts on nylon 66 fabric

		Light fastness		Wash fastness					
				Abura			Ghana Obeche		
Mordant	Sample colour on fabric	Abura	Ghana Obeche	CC	SC	SA	CC	SC	SA
$CuSO_4$	UM	1	1-2	2	3-4	3	2-3	3-4	4-5
	PreM	2	2	3	4	5	3-4	4-5	3-5
	PostM	2	2-3	3-4	5	4-5	4	4	4-5
$SnCl_2$	PreM	2-3	2	3	4-5	4-5	3-4	4-5	5
	PostM	2-3	3	4	5	4-5	3-4	4	4
$K_2Cr_2O_7$	PreM	2	2-3	3-4	4-5	4-5	4-5	4-5	4-5
	PostM	3	2-3	4	4-5	4-5	4	4-5	4-5
$FeSO_4$	PreM	2	2	3-4	4	4-5	3	4	4
	PostM	2-3	2	3	4-5	4-5	3-4	4-5	4

CC = Colour change, SC = staining on cotton, SN = staining on nylon, UM = Unmordanted, PreM = premordanted, PostM = postmordanted.

Table 3: Fastness properties of dye extracts on cotton fabric

		Light fastness		Wash fastness					
				Abura			Ghana Obeche		
Mordant	Sample colour on fabric	Abura	Ghana Obeche	CC	SC	SA	CC	SC	SA
$CuSO_4$	UM	2	1-2	2	2-3	3	2	4	4-5
	PreM	3	2-3	4	4	4-5	3	4-5	4-5
	PostM	2-3	2-3	3-4	4	4-5	4	4	4-5
$SnCl_2$	PreM	2-3	2-3	4	4-5	4	3	4-5	4
	PostM	3	3	3	4-5	4	3-4	4-5	4
$K_2Cr_2O_7$	PreM	3	2-3	4	4	4-5	4-5	4	4-5
	PostM	3	2-3	4-5	4	4-5	4-5	4	4
$FeSO_4$	PreM	1-2	2	3-4	4-5	4	3	4	4
	PostM	2	2	3	4-5	4-5	3-4	4-5	4-5

CC = Colour change, SN = staining on nylon, SA = staining on acrylic.

salt gave brown shade, the depth of colour increased on the three fabrics in the order nylon<cotton<acrylic. Thus, postmordating and premordanting are much more effective on the acrylic fabric.

Ghana Obeche dye extract

Nylon, cotton and acrylic fabrics dyed with these two dye extracts was light brown in colour without mordanting. Premordanting with copper salt and tin II salt caused the colour to become deeper brown shade. Postmordanting with potassium dichromate also gave brown shade on nylon, cotton and acrylic fabrics respectively. Thus, premordanting with copper salt and tin salt are more effective on the three substrates. The iron-mordant did not produce any reasonable change in shade on the three substrates except on cotton fabrics.

Table 4: Fastness properties of dye extracts on acrylic fabric

		Light fastness		Wash fastness					
				Abura			Ghana Obeche		
Mordant	Sample	Abura	Ghana Obeche	CC	SC	SA	CC	SC	SA
$CuSO_4$	UM	2	1-2	2	2-3	3	2	4	4
	PreM	3	2-3	3	4-5	4	3	5	5
	PostM	3	3	3-4	4	4-5	3-4	5	4-5
$SnCl_2$	PreM	2-3	2-3	3-4	4-5	4-5	4	5	5
	PostM	3	2-3	4-5	4-5	4-5	4-5	5	4-5
$K_2Cr_2O_7$	PreM	2-3	2-3	4-5	4-5	4	4-5	5	5
	PostM	3	2-3	4-5	4-5	4-5	4-5	4-5	5
$FeSO_4$	PreM	2	2	3-4	4-5	4-5	3-4	5	4-5
	PostM	2	2	3	4	4	4-5	5	5

CC = Colour change, SN = staining on nylon, SC = staining on cotton.

CONCLUSIONS

The presented results prove the possibility of using the by-products of the timber industry as a source for the dyeing of natural and synthetic textiles. The type of substrates used for dyeing affected the shade and fastness of the dye extracts. Nylon fabric for instance, gave lighter shades of brown whereas cotton and acrylic gave deeper shades respectively. Fastness to water was also observed to be higher on acrylic fabric than on nylon and cotton fabrics. The type of mordant and method of mordanting seemed to have also affected the colour shades of the dyed fabrics. Thus, potassium dichromate produced more pronounced shades especially on acrylic fabric in postmordanting than the other metal salts used. Hence, postmording is more effective on the acrylic fabric.

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