EFFECT OF TEMPERATURE ON AFFINITY OF NATURAL DYE FROM COCONUT COIR FIBRE FOR COTTON FABRIC

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Abstract

Natural dye extracted from coir fibres with Na_2CO_3 (0.1 M) solution as extracting solvent in liquor ratio 1:50 gave percentage yield of 10.06 % crude dye that was used to dye alum pre-mordanted cotton fabric using liquor ratio 1:20 at 2 % dye depth on a water bath. Dye-uptake and affinity of extracted natural dye for the treated cotton fabric varied from 52.8 mg/g to 63.2 mg/g and -8.7 $kJmol^{-1}$ to -10.7 $kJmol^{-1}$ respectively for dyeing temperature of 30 ^oC to 90 ^oC, while the enthalpy and entropy were 1.4 $kJmol^{-1}$ and 33.3 $Jmol^{-1}$ respectively, the positive values of enthalpy and entropy showed that dyeing process was endothermic and spontaneous respectively, while the negative value of the affinity of extracted natural dye for the cotton fabric indicated that dyeing process was irreversible.

Key words: affinity, coir, crude, dye-uptake, endothermic

Introduction

Dyes are mostly organic materials, which are responsible for colouring foods, pharmaceutical products, cosmetics, textile materials and beautifying our environment (Maulik and Roy 2009). Dyes which are obtained from natural sources, such as minerals, animals and plants are called natural dyes, while the man-made ones are called synthetic dyes (Gowda *et al.*, 2010). Natural dyes are grouped into two, namely substantive and adjectives dyes. The substantive dyes (e.g indigo, orchil, turmeric etc) require no pre-treatment to enhance their fixation to the substrates, while adjective dyes (eg alizarine, madder, cochineal, logwood etc) do have their hue enhanced, intensified and hooked to the substrates with the aid of mordants, like alum, copper sulphate, ferrous sulphate (Siva, 2010; Gulrajani, 2001). The major merits of natural dyes over its synthetic counterpart are eco-friendly and non-carcinogenic nature (Deo, 2007; Deo, 2010), equally, find application chiefly in medicine as purgastive, astringent tonic and antioxidant (Chakraborty *et al.,* 2010).

Systematic approach towards extraction and purification of natural dyes is one of the ways to bring success to the production and application of the natural dyes. The traditional method of extracting dye from plants is aqueous extraction method, while the conventional methods of obtaining dyes from dye yielding plants are solvent, sub critical water and supercritical fluid extraction (Chakraborty *et al.,* 2010). Aqueous extraction method makes use of water as an extracting solvent, it operation is cheaper than any other extraction method but the yield is low to meet up with industrial need (Gowda et al., 2010; Sudhakar *et al.,* 2006). Supercritical fluid extraction that make use of CO_2 as dye extracting fluid, has higher yield than sub critical water extraction, though highly purified dye is obtainable from both extraction method with a demerit of high operating cost (Mongkholkhjornslip *et al.,* 2004). Solvent extraction method gives dyestuff with shade containing high percentage of colour imparting chromophore, unlike aqueous extraction method that gives dyestuff with poor shade, because of the presence of chromophore containing other non-colour imparting matters and it also has advantage of low operating cost in relation to both sub critical water and supercritical fluid extraction method (Herodez *et al.,* 2002).

The four techniques of dyeing fabric are conventional, sonicator, microwave and supercritical dyeing method. The conventional dyeing is carried out by boiling the fabric in dye bath for specific period of time; it is the cheapest and most common method of dyeing (Gowda *et al.,* 2010). Sonicator dyeing makes use of ultrasound energy in migration of dye molecules from the dye-bath to the fabric, microwave dyeing makes use of high frequency (2450 MHz) microwave field to influence vibration and collision of dye molecules with the molecules of the fibre (Chakraborty *et al.,* 2010), while supercritical dyeing method makes use of CO_2 to influence migration of dye molecules into the fabric matrix. But due to high equipment cost, sonicator, microwave and supercritical dyeing methods are rarely adopted on a commercial scale, despite their improved dye utilisation, energy saving by dyeing at lower temperature, little or no addition of auxiliary chemical and shorter dyeing time advantages over conventional dyeing method (Chakraborty *et al.,* 2010; Herodez *et al.,* 2002).

This research was designed to use aqueous extraction method in extracting dye (from coir fibre) that was used to dye cotton fabric (using conventional dyeing method) and determine effect of temperature on affinity of the extracted coir natural dye for cotton fabric.

Experimental

Materials

One yard of grey fabric was obtained at oke odo market, Lagos, and coir (coconut) fibres were obtained from Cassava Avenue, FUTA road, Ondo state, Nigeria for this study. The chemicals used during the course of this research were obtained from the British Drug House Limited (BDH) and were of analytical grade.

Methods

Cotton fabric pre-treatments

The grey fabric was desized, scoured, bleached and mercerized as described by Adetuyi et al., (2009), to remove starch sizing, natural colour and dirt from the grey fabric as well as to open up fabric matrix for dyeing process.

Extraction of colourant

The coir fibres were chopped and the colourant (dye) were extracted using aqueous extraction method by boiling chopped fibres in a beaker containing 0.1M Na_2CO_3 at liquor ratio 1:50 for 20 min (Noah, 1995). The alkaline dye liquor-fibre solution was filtered to separate fibre from the dye-liquor and the dye liquor filtrate was then subjected to evaporation to obtain the dye in a dry solid form of brown colour. The obtained brown dye was then ground to powdery form and used for dyeing the pre-treated cotton fabric without any further purification (i.e used as crude dye).

Mordanting

Pre mordanting was done with 5 % analytical grade alum mordant on the cotton fabric, with liquor ratio 1:20 (distilled water) and boil for 30 min. After mordanting, the sample was taken out, thoroughly rinsed with distilled water and air dried.

Standardization of dye solution and dyeing of pre-mordanted cotton fabric

Brown coir dye solution (0.3 g/L) was prepared by weighing 0.3 g coir dye into 250 mL beaker containing 0.125 g NaCl and little quantity of distilled water was added to make a paste. More quantity of distilled water was added to the paste to make a solution that was transferred into 1 L standard flask and the dye solution was finally made up to the marked point on standard flask with distilled water. The coir dye solution was standardised on camspec spectrophotometer, where 510 nm was obtained as wave length of maximum absorption λ_{max} , that was used to measure absorbance of various concentrations of the dye solution in accordance to Beer-Lambert's law.

Conventional dyeing of pre-mordanted cotton fabric (2.5 g) in an open beaker was done with 50 mL of 0.3 g/L coir dye liquor at 30 ^{o}C for 1 h using liquor ratio 1:20 and dyeing depth 2 %. The absorbance of the effluent from dyeing process was read on camspec spectrophotometer and its concentration extrapolated from the plotted working curve. The same procedure was repeated for fabric dyed at 50, 70 and 90 ^{o}C.

Thermodynamic study

Data obtained from dyeing process was used to do thermodynamic study that gave comprehensive information on affinity of the extracted coir dye for the cotton fabric, besides, enthalpy, entropy and activation energy of dyeing process.

Results and discussion

It was observed that aqueous extraction of 100 g coir fibres gave 10.06 g of crude dye, which was 10.06 % yield. This yield showed the possibility of extracting dye stuff from agro-waste material that could serve as a means of converting waste to wealth.

The working curve shown in Figure 1 was prepared from the results of absorbance obtained from running camspec spectrophotometer at 510 nm on series of coir dye solutions of different concentrations. The graph was reproducible and linear over the calibration range; therefore, it was used for this study.

Dyeing

Table 1 showed that the concentration of coir dye absorbed by the cotton fabric and dye-uptake increased with increased in dyeing temperature, this quite agreed with the findings made by Popoola et al., (2009) in effect of temperature on dye-uptake of procion yellow R. dyed cotton fabric.

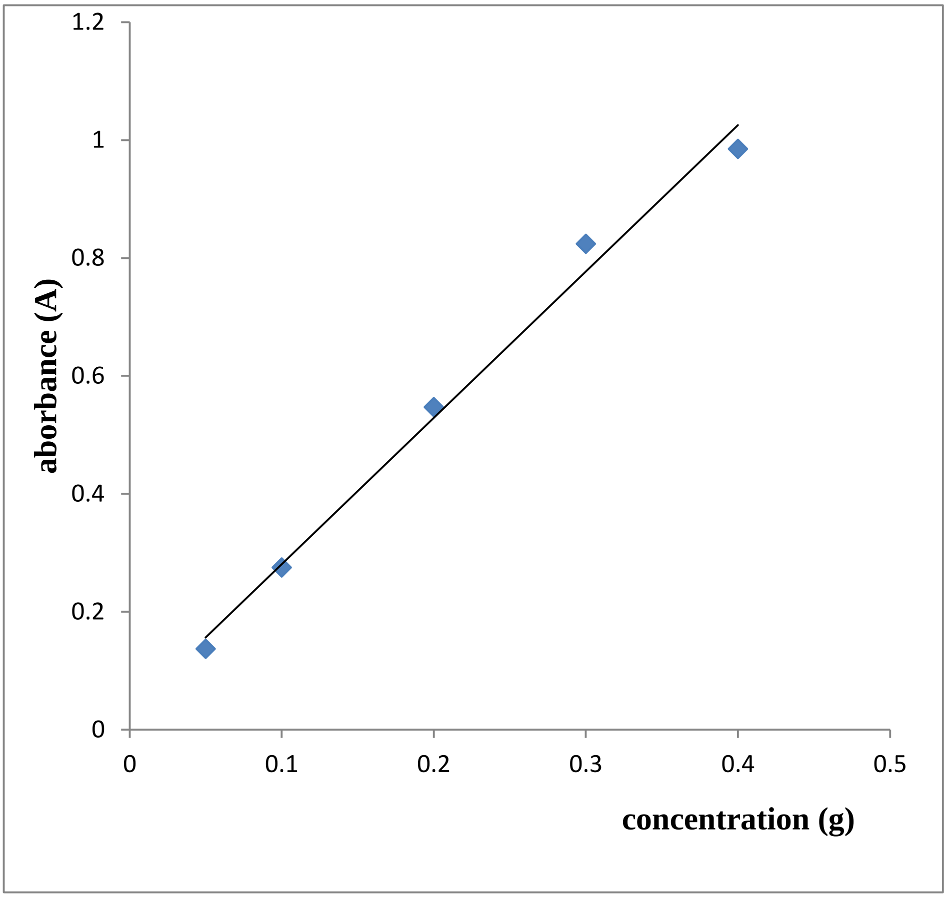

Figure 1: Absorbance against concentration of coir dye

Table 1: Dye-uptake of the dyed fabric at different temperature

Temp. (^oC)	Abs. (A)	Conc. of dye effluent C_e (g)	Conc. of dye in fabric C_f (g)	Dye-uptake (mg/g)
30	0.427	0.156	0.144	57.6
50	0.417	0.149	0.151	60.4
70	0.409	0.145	0.155	62.0
90	0.402	0.142	0.158	63.2

Thermodynamic study

Extraction thermodynamics

Thermodynamics parameters (ΔH, ΔS and $\Delta\mu$) for dyeing process can be determined using second law of thermodynamic equations,

$\Delta\mu = \Delta H - T\Delta S$ ………………………………………………. (1)

$\Delta\mu = -RT \ln K_o$ ……………………………………………..... (2)

$E_a = \Delta H + RT$ ……………………………………………….. (3)

Equating (1) and (2) gives (4) below;

$\log K_o = (\Delta S/2.303R) - (\Delta H/2.303RT)$ …………………….…… (4)

$K_o = C_f/C_e$ ……………………………………………................. (5)

Where, K_o is equilibrium constant, C_f is quantity of dye absorbed by the cotton fabric at equilibrium temperature, C_e is the quantity of coir dye remain in the effluent at equilibrium temperature, R is gas constant, while ΔH, ΔS, E_a and $\Delta\mu$ are enthalpy, entropy, activation energy and affinity of coir dye for mordanted cotton fabric.

The values of K_o , E_a and $\Delta\mu$ for dyeing process were determined using equations (4), (3) and (1) respectively and are given in Table 2. The values of enthalpy and entropy of dyeing were gotten from Van't Hoff plot (Fig. 2) to be 1.413 KJmol^{-1} and 33.262 Jmol^{-1} respectively. The positive values of enthalpy and entropy of dyeing indicated that the dyeing process was endothermic and spontaneous respectively while the negative values of free energy indicated that the dyeing process was irreversible.

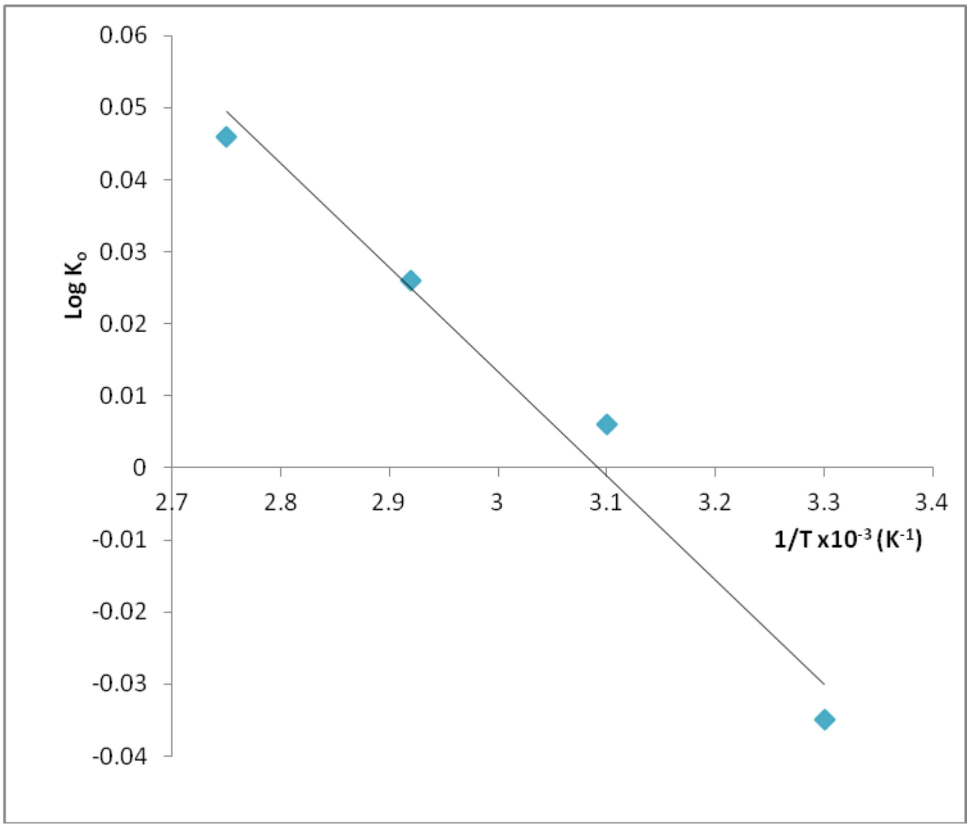

Figure 2: Van't Hoff graph

Table 2: Equilibrium constant, activation energy and affinity of coir fibre for mordanted cotton fabric

Temp. (^oC)	$T^{-1} X 10^{-3}$ (K^{-1})	ΔG ($KJmol^{-1}$)	E_a ($KJmol^{-1}$)	K_o
30	3.30	-8.67	3.93	0.923
50	3.10	-9.33	4.10	1.013
70	2.92	-10.00	4.26	1.069
90	2.73	-10.66	4.43	1.113

Conclusion

The reasonable dye yield from extraction process showed that extraction of dye stuff from agro-waste material can serve as a means of converting waste to wealth, because of its good potential of being used as a raw material in paint, food, pharmaceutical industries and the good value of dye-uptake of the dyeing process and brown colour of the dyed cotton fabric showed that the extracted dye can be applied in textile industry.

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