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COMPARATIVE STUDY OF THE FASTNESS OF ANNATTO AND PROCION YELLOW R ON CELLULOSIC FABRIC

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ABSTRACT

Annatto dyed cellulosic fabrics performed favorably better than Procion yellow-R when treated with soap and perspiration solutions; and exposed to light and dry heat. Both were fast and stable to perspiration and hot pressing. Annatto was very fast to washing than Procion yellow-R, having a rating of 4.5 on a scale 5. It was however, less stable to high energy radiation than the synthetic dye. Its calculated molar absorptivity at 545nm was 13,600 l mol^{-1} cm^{-1} while Procon yellow R dye has 16,000 l mol^{-1} cm^{-1} at 413nm.

KEY WORDS: Fastness, Annatto, Procion Yellow-R, Dyeing, Spectra

INTRODUCTION

The durability of dyes and pigments on substrate are generally assessed though their actions against various agencies encountered in usage. These agencies include liquid and non – liquid treatments. The liquids treatments are wet processes as washing with soap or water alone, bleaching solutions, acidic or alkaline solution and perspiration and dry cleaning with non-aqueous solvents. The non-treatments involve rubbing, exposure to light and dry heat. The ability for the colourant to withstand / resist these agencies without losing their colour is termed fastness (Giles,1974). The fastness of any dyes determines its areas of usefulness. A light fastness dye implies its stability towards high energy radiation and vice-versa.

Annatto, a natural dye, obtained from Bixa orellana, has been adequately reported in literature as colourant for food and other substrate (Kochhar,1981). Little or no references have been made in regards to its fastness on cellulosic fabric. In view of the wide usefulness of this dye, this paper examines by comparison its fastness with a synthetic dye, Procion Yellow R, on cellulosic fabric to washing, perspiration, dry ironing and light.

MATERIALS AND METHODS

Dyes Sources

The annatto dye (Molar mass 394 a.m.u) was extracted from the red pulp of the plant, Bixa orellana, with chloroform and then purified over silica gel G 60 in an open column chromatography with blended solvents (Adetuyi, 2003, Preston and Richard 1980).

The synthetic dye, Procion Yellow-R (Molar mass 623 a.m.u) was obtained from Textile mills, Ikeja, Lagos, Nigeria.

ABSORPTIOMETRIC MEASUREMENT OF THE DYES

2.5 x 10^{-5} gl^{-1} and 2.5 x 10^{-4} gl^{-1} stock solutions of Annatto in chloroform and Procion Yellow-R in acetone were prepared respectively. An aliquot was taken for serial dilution with chloroform or acetone and absorbance was measured on Biochrom-4060-UV-Visible spectrophotometer at 545nm or 413nm. The molar absorptivity of the dyes in a 1% solution and 1-cm cell $\left(A\,^{1cm}_{1\%}\right)$ were determined using the Beer-lambert's relationship (Giles,1974):

$$A = \mathcal{E}\,cl \quad \text{------------------------} \quad (2.1)$$

where A is the Absorbance (A)
l - is the cell path length in cm.
C - is the concentration in g per 100ml (& w/v) and
$\mathcal{E}$ - is the molar absorptivity or molar extinction coefficient in l mol^{-1} cm^{-1}.

Since the molecular weights of the dyes are unknown, the molar extinction coefficient $\mathcal{E}$ is represented by the symbol $\left(A\,^{1cm}_{1\%}\right)$ and is generally used for the comparison of absorption intensity.

$$\left(A\,\begin{matrix}1cm\\1\%\end{matrix}\right) = \frac{A}{cl} \quad \ldots\ldots\ldots\ldots \quad (2.2)$$

It is related to the molar absorptivity by the expression:

$$\mathcal{E} = \left(A\,\begin{matrix}1cm\\1\%\end{matrix}\right) \; M/_{10} \quad \ldots\ldots\ldots\ldots \quad (2.$$

Where M is the molecular weight of the dye.

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THE DYEING PROPERTIES

Dyeing of the cellulosic fibres

The Annatto and Procion yellow R dyes were used one after the other for dyeing on scoured and bleached white cellulosic fibres (yarn and fabric) without prior application of a mordant. Each dyeing was done at two different depths 2% and 5% for cotton yarn and fabric respectively in an infinite dyebaths in which the concentration of the colourants were assumed constant. The recipes followed were proportional to the weight of the goods (Giles, 1974, White, 1980). They were dyed in a single-bath dyeing machine MBMK II.

(a) Dye-uptake measurement.

The different baths for each dye were used. Annatto dyebath contains $4\,gl^{-1}$ (dye)(2.5ml), 30% (o.w.f.) sodium chloride(5ml) and 3% (o.w.f) sodium hydroxide(10ml);while the synthetic dyebaths has a reduced amount of NaoH (2.5ml) and 10% (o.w.f) Na_2CO_3 (2.5ml) alongside with other equivalent recipe as annatto.All in a liquid-to-goods ratio of 100:1.A blank bath each of the same liquor ratio were also prepared for 2% dyeing of 500mg cotton yarns. One dye bath each serves as a standard solution from which various aliquots were taken for serial dilution. Their optical density were measured on Biochron - 4060 spectrophotometer at λ_{max} 452nm (Annatto) and 416nm (Procion yellow-R). The other baths and blanks were transferred into the dyetubes mounted inside the dyeing machine and set at the dyeing temperature of 60^0C or 80^0C. On attainment of the temperature, the pre-soaked cellulosic yarn at the same temperature was introduced into the dye tube and dyeing commences. Sampling of the spent dye-liquor, about 2ml, was taken at intervals of 30 min for a period of 3hr. Prior to sampling; dyed yarns were removed from the dye-liquor. Equivalent aliquot from the blank liquor was introduced into the dye liquor to replace the dye assistants that had been removed by the dyed yarn. The dyed yarns were returned and dyeing continues till the next sampling period. The sample solutions were diluted and their optical density measured. The dye-uptakes were determined using equation 1.

$$\frac{1000.C_{Df}}{W_{Df}} \text{ ------------------------- } (1)$$

where W_{Df} is weight of dyed cellulosic yarn (0.5gm)
C_{Df} is the concentration of dye in yarn (%w/v), which is given by equation (2): $C_{Df}=0.02 - C_{Ds}$ ---------------- (2)
Where, 0.02 (%w/v) is a constant (initial concentration of dye-liquor).
and C_{Ds} is the concentration of spent dye liquor at various time intervals of dyeing, deduced from the calibration curve.

After the dyeing operation, the yarns were removed form the dyebath and properly washed in a mild soap solution before being rinsed in cold distilled water and dried.

(b) Tensile properties of yarns

The load – elongation curves were obtained for the dyed cellulosic yarns with Annatto and Procion yellow-R of various lengths at constant – rate-of-elongation of 500.0 mm min^{-1} and 500 N per tension on Instron tensile tester T5000.

(c) The assessment of fastness .

Each dyebath for a 5% dyeing of the dyes on cellulosic fabric (6g) in liquor ratio of 30:1 contains: 30ml of the dye solution (1g/100ml), 30% (o.w.f) sodium chloride (18ml) and 5%(o.w.f.) Sodium hydroxide (6ml). The dyeing was carried out for 3h at 60^0C after which the fabrics were removed from the dyebaths and treated as the previously dyed yarns and fixed with hot iron.

Assessment of four fastness properties namely: washing, perspiration, hot pressing (Heat treatment) and light was carried out on the dyed fabric according to the International Standards Organisation (ISO) procedures (SDC,1992). Under each test, 10 specimens of the dyed articles were tested and the mean value of the results obtained taken as the fastness ratings for the test.

RESULTS AND DISCUSSION

The physical parameters obtained for the dyes are shown in Table 1. They have relatively high molar absorptivity above 10,000 l $mol^{-1}cm^{-1}$. These values are measure of the strength of the dyes (Griffths, 1987). Both dyes also impacted brilliant and appealing shade of their hues to the celllulosic fabrics (Table 1).

Table 1: The Physical Parameters Obtained from Annatto and Procion Yellow R dyes.

Test Performed	Annatto	Procion Yellow R
Colour	Orange – red crystals	Golden yellow
% Recovery	3.5 %	-----
Molar absorptivity l (mol^{-1} cm^{-1})	13,600	16,000
Wavelength maximum (λ_{max}) nm	545	413
Colour imparted on dyeing (i) Cellulosic yarn (ii) Cellulosic fabric	 Orange Orange	 Yellow Yellow
Molar mass (a.m.u)	394	623

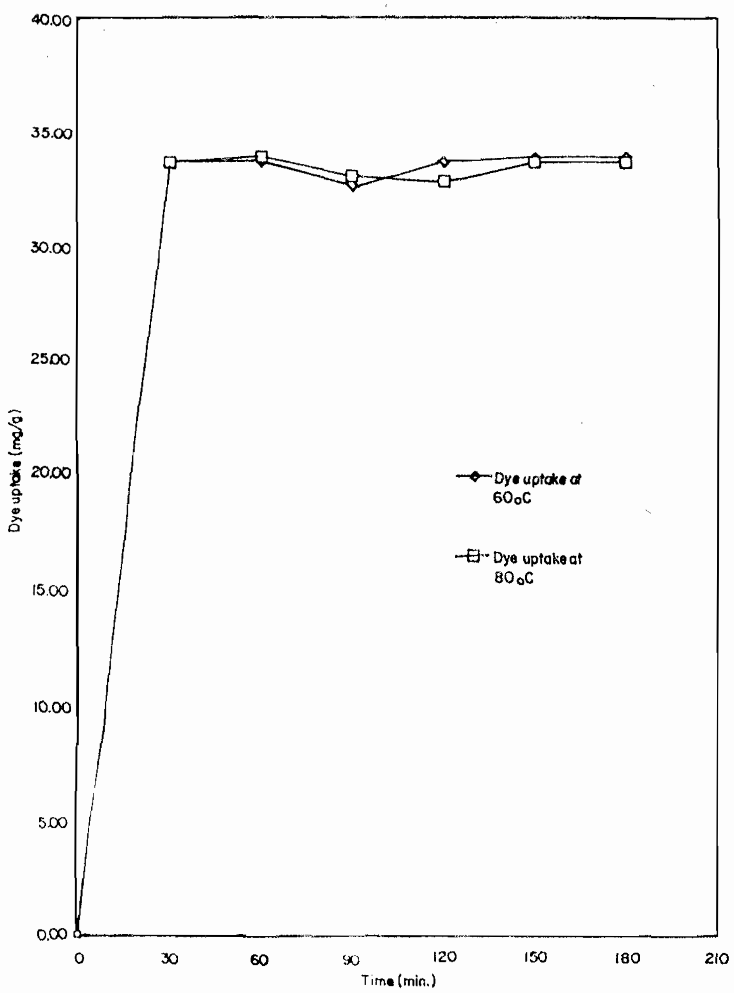

Fig. 1: The Equilibrium status of dye-uptake for cotton yarn in Procion yellow R dye at various time intervals at 60° C and 80° C

Table 2: Tensile Properties of Dyed Yarns* at 60°c and 80°c

Cotton dyed yarns	Temperature °C	Breaking load (N)	Extension at break Ir (mm)	Breaking Extension (%)	Initial modulus (N/tex)
Procion yellow Dyed yarns	60 80	41.49 57.56	28.96 39.90	19.31 26.60	2.75 3.75
Annatto dyed yarns	60 80	42.19 41.81	23.98 45.40	15.99 30.27	3.75 1.80
Undyed yarns acts as control	-	45.51	40.06	26.71	2.14
Blank D++		43.10	28.33	18.89	2.75

* 150-mm means test length; speed 500mm min^{-1}; Range 5,000 NT^{-1}

++ Blank D – White cotton yarn treated with 10ml NaOH solution

Equilibrium dye-uptake

The equilibrium status of dye-uptakes of the two dyes Procion Yellow-R.and Annatto is shown in fig 1 & 2 respectively. Both fig 1& 2 showed initial increase in the dye uptake with time, obeying Fick's law of diffusion until equilibrium level is reached (Jones, 1975). Both dyes showed higher equilibrium dye uptake at lower dyeing temperature of 60°c than at 80°c and this was in line with the expected behaviour of a direct colouration of dyes on cellulosic fabrics (Giles, 1974). It also implies that at 60°C the two dye molecules are more retained in the accessible regions (amorphous) of the yarns/ fabrics (Burdett, 1975).

However, the Procion yellow-R curves conformed perfectly to the direct curve more than the annatto curves (Fig. 1). The Procion curve indicated that the dye can still be used at higher temperature (80°C) because the two curves (Fig.1) intercepted after 90mins

Table 3 : Fastness ratings of Annatto and Procion yellow R dyed cellulosic fabric

Fastness test specimen	Washing	Perspiration	Hot pressing	Lights
1	4+	3	4	3+
2	4+	3+	3	3
3	4	3	4	3+
4	5	3	4	2+
5	4+	3+	4+	2+
6	4	3	4	3
7	4+	3	4+	3
8	4+	2	4	2+
9	5	3	4	3
10	4+	3	4	3+
Mean fastness rating	4.5	3.0	4.0	3.0
Mean fastness rating (Procion Yellow R dyed fabric)	3.5	4.5	4.0	4.0

Key: Grey scale rating:
1 – 2 --------- low fastness
3 – 4 --------- moderate fastness
5 – 6 --------- high fastness

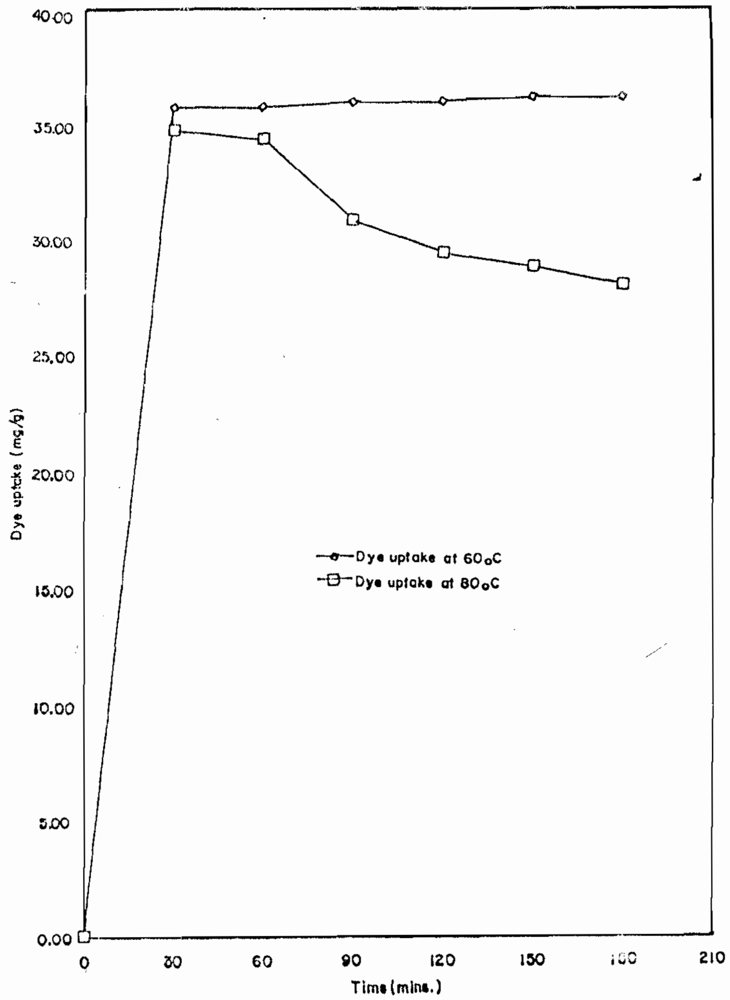

Fig. 2: The Equilibrium status of dye-uptake for cotton yarn in Annatto dye at various time intervals at 60°C and 80° C.

of dyeing. Annatto dye absorption on celluosic fibres is favoured only at low temperature. The discrepancy in the behaviour of these two dyes might be attributed to their purity. The purity and the composition of annatto dyes are not certain. Coordination, association and aggregation of the dye molecules are possible at both dyeing temperatures in annatto dye solution (Giles,1975) than in the synthetic (Priocion yellow-R) where its composition is fairly stable.

Tensile Properties of the dyed cellulosic yarns.

The data of the tensile properties of the dyed cellulosic yarns at the chosen dyeing temperatures are presented in Table 2. The data show that the extensibility and strength of the dyed Annatto and Procion yellow-R yarns at 600C were greatly improved than the undyed yarn which acts as control.

The initial modulus of the two types of dyed yarns at this temperature were higher, indicating and corroborating the accessibility and retention of the dye molecules into the fibre matrix, thereby acting as fillers and increases strength. Also, the formation of dye-fibre bond (covalent) and hydrogen bonding between the Procion yellow-R , annatto and the cellulosic fibres respectively, possibly assisted in the strength. The dye-fibre bond results from the attachment on the heterocyclic cabon of the Procion yellow-R by the nucleophilic group, cellulosate anion (cell-O^-) of the cellulose. (Rys and Zollinger, 1975). The hydrogen bonding, which is a physical adsorption, resulted from the presence of oxygen-containing functional groups of the annatto dye and cellulose. At 80^0C however, Procion yellow -R dyed yarns were of better strength than Annatto dyed yarns and this might be due to more accessible region made available for covalent bond formation within the fibres.

Fastness properties of the Dyed Fabrics

The results of the fastness properties of annatto and Procion yellow R dyed cellulosic fabrics are summarized in Table 3. They were uniformly dyed of the dyes' hues. Both dyes show good fastness ratings of 4.0 on a scale of 5 to hot pressing, indicating the stability of the two dyes to heat. In other words, the dyes are stable to sublimation. The hues of both dyed fabrics were stronger and the dyes were able to migrate and form large particles within the fibres and their true colours developed. Annatto dyed fabrics was very fast to washing than the Procion yellow R dyed fabrics. There was no significant loss in both depth and hue of the dyed fabric of Annatto in solution. Procion Yellow -R dyed fabrics changed slightly in depth as some of its dye blends in washing solution. Both dyed fabrics behaved alike in perspiration solutions having a deeper colour. However, annatto dyed fabrics were less fast, rated 3.0 on a scale of 5 to perspiration.

The light fastness results of the two dyed fabrics on a scale of 8 revealed that procion yellow R dyed fabric rated 4.0 was fairly stable than the annatto dyed fabric rated 3.0, to high energy radiation.Najar et al (1988) had reported the low resistance of annatto extract to light. Nevertheless, considering all other performance of annatto dyed fabrics to the synthetic, Procion yellow-R, particularly to other agencies discussed above, and been applied in the absence of any mordant, either synthetic or natural, the annatto dye, therefore, would be considered substantive as that of the procion yellow R dye to cellulosic fabrics. Another natural dye, Ginger, which had been reported to be substantive to cellulosic fibres, has a better fastness to light (Popoola, et al, 1994) as well as poor fastness to wash when compared to annatto.

The limitation imposed by its low yield for annatto (3.5%), just as ginger, would make the dye useful for textile cottage industry for the production of indoor and evening wearing apparel, where exposure to light is minimum.

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