DYEING CHARACTERISTICS AND FASTNESS PROPERTIES OF DISPERSE DYES ON POLYESTER AND NYLON 6.6 FABRICS

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ABSTRACT

Five different azo disperse dyes were applied on polyester and nylon 6.6 fabrics using appropriate methods. At the end of the dyeing process the fabrics were investigated for their fastness properties. All the azo disperse dyes showed good to very good light fastness properties and very good to excellent wash fastness properties when subjected toInternational Standard Organization (ISO) washing tests. In addition, each of the dyes gave a wide range of reddish brown to indigo shades with very good depth and levelness on fabric after dyeing.

Keywords: Polyamide fibre, Polyester fibre, Disperse dye, Fastness properties.

INTRODUCTION

Intensive research efforts have been made for the past six decades in the area of disperse dyes used for the colouration of hydrophobic fabrics (Dawson, 1978, 1983; Maradiya and Patel, 2001a; Maradiya and Patel, 2001b; Maradiya and Patel, 2002; Patel *et al.,* 2003). Disperse dyes in particular have become the focus of attention in view of their hydrophobic nature and their popularity as colourants for polyester fibres. Disperse dye has derived its name for its insolubility in water and the need to apply it from an aqueous dispersion. Disperse azo dyes, have aromatic moieties linked together by azo (-N=N-) chromophores, have been continuously used in the textile industry (Neamtu, *et al*., 2004). Disperse dyes have some characteristics such as colloidal dispersion and very low water solubility. These dyes can be applied to synthetic fibres such as polyester,nylon, acetate, cellulose and acrylic (Akbari, *et al*., 2002). Disperse dye exists in the dye bath as a suspension or dispersion of microscopic particles, with only a tiny amount in true solution at any time. They are the only dyes that are effective for “normal” polyester. Some types are used for nylon and acetate. Polyester fibre is a man-madefibre in which the fibre forming substance is any long-chain synthetic polymer composed of at least 85% by weight of an ester of a substituted aromatic carboxylic acid, including but not restricted to substituted terephthalic units, p(-R-O-CO- C_6H_4-CO-O-)$_x$ and para-substituted hydroxy-benzoate units, p(-R-O-CO-C_6H_4-O-)$_x$.

The most common polyester for fibre purposes is poly (ethylene terephthalate), or simply PET. This is also the polymer used for many soft drink bottles and it is becoming increasingly common to recycle them after use by remelting the PET and extruding it as fibre. This saves valuable petroleum raw materials, reduces energy consumption, and eliminates solid waste sent to landfills.PET is made by reacting ethylene glycol with either terephthalic acid or its methyl ester in the presence of an antimony catalyst. The reaction is carried out at high temperature and vacuum to achieve the high molecular weights needed to form useful fibres. PET is melt spun.

On the other hand, a nylon fibre is a syntheticfibre in which the fibre forming substance is a long-chain synthetic polyamide in which less than 85% of the amide-linkages are attached directly (-CO-NH-) to two aliphatic groups.The term nylon refers to a family of polymers called linear polyamides. There are two common methods of making nylon for fibre applications. In one approach, molecules with an acid (COOH) group on each end are reacted with molecules containing amine (NH_2) groups on each end. The resulting nylon is named on the basis of the number of carbon atoms separating the two acid groups and the two amines. Thus nylon 6,6 which is widely used for fibres is made from adipic acid and hexamethylenediamine. The two compounds form a salt, known as nylon salt, an exact 1:1 ratio of acid to base. This salt is then dried and heated under vacuum to eliminate water and form the polymer.

In another approach, a compound containing an amine at one end and an acid at the other is polymerized to form a chain with repeating units of (-NH-[CH_2]n-CO-)$_x$. If n=5, the nylon is referred to as nylon 6, another common form of this polymer. The commercial production of nylon 6 begins with caprolactam using a ring-opening polymerization.

In both cases the polyamide is melt spun and drawn after cooling to give the desired properties for each intended use. Production of nylon industrial and carpet fibres begins with an aqueous solution of monomers and proceeds continuously through polymerization, spinning, drawing, or draw-texturing. Considering the important properties of disperse dyes, polyester and nylon, it was thought interesting to explore the dyeing performance and fastness properties of five disperse dyes on polyester and nylon fabrics.

MATERIALS AND METHODS

Materials

The nylon 6.6 fabric and the 100% polyester fabric were products of (Ciba Geigy) obtained from Oshodi market in Lagos State, Nigeria. All of the chemicals used were of commercial grade and were further purified by crystallization and distillation. All solvents used were either of analytical grade or redistilled commercial grade. The synthesized disperse dyes were provided by the Department of Chemistry, University of Benin, Benin City and were used without any further purification. The chemical structures, molecular weights and melting point ranges of all the dyes used are shown in Figs. 1 – 5.

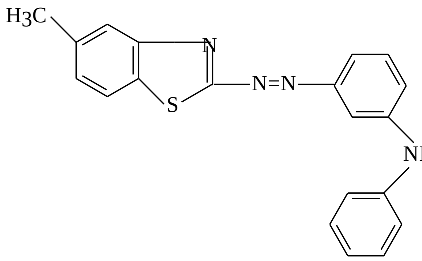


Fig. 1: 2-methyl-benzothiazole-azodiphenylamine (Dye A)
[Molecular weight: 344g/mol, Melting point: 144-146°C]

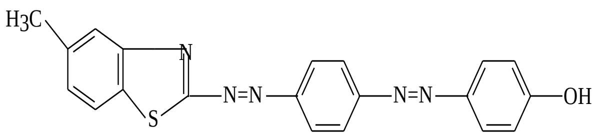


Fig. 2: 4-methyl-azo-1,3- dihydroxylbenzo-azo phenol (Dye B)
[Molecular weight: 370g/mol, Melting point: 156-158°C]

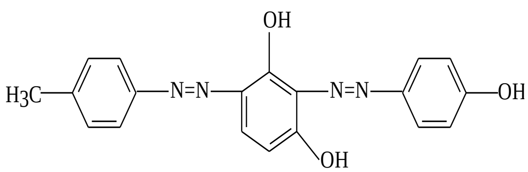


Fig. 3: 4-methyl-azo-1,3- dihydroxylbenzo-azo phenol (Dye C)
[Molecular weight: 405g/mol, Melting point: 204-206°C]

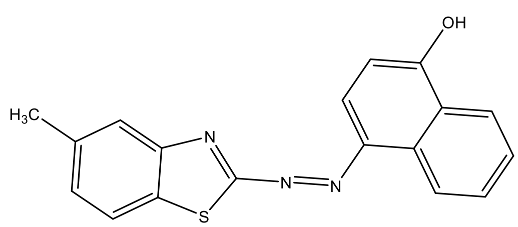


Figure 4: 2-methylbenzothiazole-azo-1-naphthol (Dye D)
[Molecular weight 319g/mol, Melting point: 140-142°C]

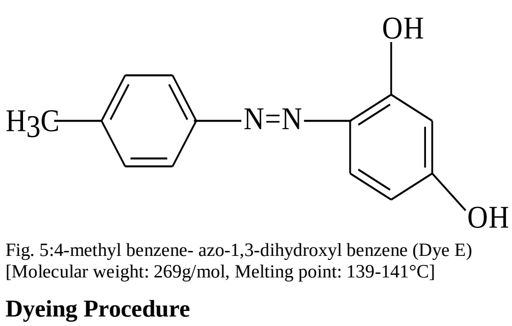


Fig. 5:4-methyl benzene- azo-1,3-dihydroxyl benzene (Dye E)
[Molecular weight: 269g/mol, Melting point: 139-141°C]

Dyeing Procedure

From each of the disperse dyes, 0.5g was weighed and dissolved in 50ml water at room temperature to form a 1.0% solution of the disperse dyes. The solution was stirred thoroughly and 0.15ml of Turkey red oil (dispersing agent) was added for effective dispersion of the dye in the water. From each of the dyes solutions, 1.5ml, 3ml and 6ml of the dye solutions werepippetted and placed in a test tube in a Dye Master. All dyeing were carried out using a liquor ratio of 1:10. Three depth of shade 0.5%, 1.0% and 2.0% nominal on weight of fabric were used. Dyeing was carried out according to specified procedures for dyeing; nylon at the boil using a carrier and polyester at 130^0C using a pressure dyeing machine (Giles, 1974). The dye bath was allowed to cool to room temperature after which the fabrics were removed and thoroughly rinsed.

Fastness Testing

Wash Fastness Test: the wash fastness of dyed samples was determined according to the International Standard Organisation (ISO) washing test number 3 (ISO, BO2, ISO, 1989). The dyed samples weighing 0.25 ± 0.02 g was cut and sandwiched between cotton and the undyed material of about the same weight. 5g of soap (bar soap) was dissolved in 1litre of cold water. This served as the stock solution. The solution was stirred properly for effective dissolution and about 20mL measured out of the stock solution and placed in a washing tube with the sandwich material and washed for 30mins at 40°C. The change in colour of the tested specimens and the degree of staining of the adjacent undyed fabrics were rated against the Grey Scales. The indications in this case are 1 to 5 where 1 (poor) and 5 (excellent).

Light Fastness Test: The light fastness was assessed by exposing the fabrics to the Xenon arc Lamp of a Fedo meter, according to the conditions of AATCC Test Method 1.6 E-1990 (AATCC, 1990; ISO, 1994). A small piece of the polyester and polyamide weighing 0.25 ± 0.02g was cut and mounted on pattern cards (Blue Wool Scale). The exposed side was labeled E and the unexposed side labeled UE. The cards were placed in a FadeoMeter, the light turned on and left for about 72hours so that an appreciable colour change exist with respect to the unexposed side. The conditions for the test were: Black panel temperature 63°C, dry bulb temperature, 43°C; relative humidity 30%. After testing, the samples were rated against standard blue wool samples (Grade 1-8) and the indications for the Grey Scale for light fastness were 8-Maximum, 7-Excellent, 6-Very good, 5-Good, 4-Fair, 3-Moderate, 2-Slight, 1-Poor.

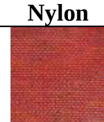
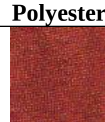
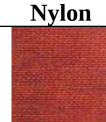
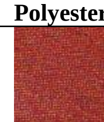
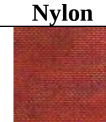
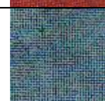
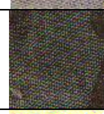
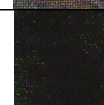
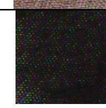
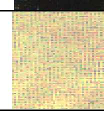
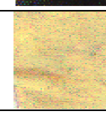
RESULTS AND DISCUSSION

Dyeing Properties

Table 1 shows that the hues of most the dyes on the fabrics were very good. The uptake of disperse dyes by fabrics takes place by the progressive adsorption of the small concentration of dye in solution, which is always present in an aqueous dispersion. The substantivity of the dye, which determines its tendency to partition in favour of the fabric, depends on factors such as molecular size, geometry and in particular, the polarity of the molecule (Shuttleworth and Weaver, 1990). The higher hue on the polyester fabric is expected due to the relatively open structure, consequently, it is expected that the diffusion of the dye within the polyester fabric would proceed rapidly under the given dyeing condition better than the nylon fabric. Hence, the rate of diffusion of the dye molecules into the polyester fabric is expected to be higher, which increases the hue value (Gregory, 1994).

All the disperse dyes were applied on polyester and nylon fabrics at 0.5, 1.0 and 2% shade.Most of the dyed fabrics gave attractive colour shades with good levelness of the dyes on the fabrics especially the 2% shade. As can be seen from the Table 1, dye E gave a very poor hue on both the polyester and nylon fabrics owing to the relative low melting point of the dye as a result, the dye was easily lost to the solution hence not firmly attached to the fabric. The variations in shades of the dyed fabrics are due to the nature and position of the various substituent present on the ring (Joseph *et al*, 2010).

Table 1: Hue of dyed fabrics

DYES	0.5% SHADE		1.0% SHADE		2.0% SHADE	
	Polyester	Nylon	Polyester	Nylon	Polyester	Nylon
A						
B						
C						
D						
E						

The effects of disperse dyes on polyester and nylon fabrics

Grading: Asides the Light Fastness properties which were rated on the scale of 1-8, all the other properties were graded from 1 to 5, where 1- poor, 2- not very satisfactory, 3- satisfactory, 3.5-moderate, 4-good, 4.5-very good and 5-excellent.

DYE A: As can be seen from Table 2, dye A gave very bright red shades with good built up and high tinctoral strength on both fabrics. The dye is substantive to both fabrics with good leveling effect. Dye A gave dyeing of satisfactory to good wash fastness and good to excellent light fastness properties. In general, dye A is highly suitable for dyeing both the polyester and nylon fabrics.

Dye B: This dye gave bright blue shades with the dye giving a better hue on polyester than the nylon fabrics as can be seen from Table 3. This dye is highly substantive to both fabrics with a very good level dyeing, brightness and built up on both fabrics.

Dye B gave only satisfactory wash fastness properties on both fabrics, with very good to excellent light fastness properties. Dye B is highly suitable in applications where light fastness is of more importance than wash fastness. Generally dye B is suitable for dyeing both polyester and nylon fabrics.

Dye C: Brown shades on both the polyester and nylon fabrics were obtained as can be seen from Table 1. Physical properties such as substantivity, level dyeing brightness and built up were between good and poor as shown in Table 4. The dye gave better wash and light fastness properties on the polyester than nylon fabrics. Dye C is more suitable for polyester than nylon fabrics.

Dye D: This dye gave bright black shades for polyester and fairly bright black shades for nylon (Table 1). From Table 5, it can be seen that the polyester fabric gave better physical properties such as substantivity, level dyeing, brightness and built up than the nylon fabrics. Also the fastness properties (wash and light) gave higher values on the polyester than the nylon fabrics. Generally this dye is fairly suitable for dyeing of both polyester and nylon fabrics

Table 2: Effects of Dye A on Polyester and Nylon Fabrics

Dye A: 2-methyl-benzothiazole-azodiphenylamine

Properties	Polyester			Nylon		
% Shade	0.5%	1.0%	2.0%	0.5%	1.0%	2.0%
Substantivity	4.5	4.5	4.5	4.5	4.5	4.5
Level dyeing	4	4	4	4	4	4
Built-up	4	4	4	4	4	4
Brightness level	4.5	4.5	4.5	4	4	4
Colour shade	V.L.RED	L.RED	RED	V.L.RED	L.RED	RED
Wash fastness	3	3	4	3	3	4
Light fastness	6.5	6.5	7	5	6	6.5

Table 3: Effects of Dye B on Polyester and Nylon Fabrics

Dye B: 4-methyl-azo-1,3- dihydroxylbenzo-azo phenol

Properties	Polyester			Nylon		
% Shade	0.5%	1.0%	2.0%	0.5%	1.0%	2.0%
Substantivity	4.5	4.5	4.5	4.5	4.5	4.5
Level dyeing	4	4	4	4	4	4
Brightness level	4	4	4	4	4	4
Built-up	4.5	4.5	4.5	4	4	4
Colour shade	L.BLUE	BLUE	D.BLUE	V.L.BLUE	L.BLUE	BLUE
Wash fatness	3	3	3	3	3	3
Light fastness	7	6.5	6.5	7	6.5	6

Table 4: Effects of Dye C on Polyester and Nylon Fabrics

Dye C: 4-methyl-azo-1,3- dihydroxylbenzo-azo phenol

Properties	Polyester			Nylon		
%Shade	0.5%	1.0%	2.0%	0.5%	1.0%	2.0%
Substantivity	4	4	4	4	4	4
Level dyeing	4	4	4	3	3	3
Brightness level	3.5	3.5	3.5	3	3	3
Built-up	2	2	2	2	2	2
Colour shade	V.L.BROWN	L.BROWN	BROWN	V.L.BROWN	L.BROWN	BROWN
Wash fastness	2	3	4	2	3	3
Light fastness	7.5	7	6	-	-	6

Table 5: Effects of Dye D on Polyester and Nylon Fabrics

Dye D: 2-methylbenzothiazole-azo-1-naphthol

Properties	Polyester			Nylon		
%Shade	0.5%	1.0%	2.0%	0.5%	1.0%	2.0%
Substantivity	4	4	4	3	3	3
Level dyeing	3	3	3	3	3	3
Brightness level	4	4	4	3	3	3
Built-up	2	2	2	1	1	1
Colour shade	L.BLACK	BLACK	D.BLACK	V.L.BLACK	L.BLACK	BLACK
Wash fastness	3	4	4	2	3	3
Light fastness	5.5	5	5	5	4.5	4.5

Table 6: Effects of Dye E on Polyester and Nylon Fabrics

Dye E: 4-methyl benzene- azo-1,3-dihydroxyl benzene

Properties	Polyester			Nylon		
%Shade	0.5%	1.0%	2.0%	0.5%	1.0%	2.0%
Substantivity		3	2	2	2	2
Level dyeing	2	2	2	2	2	2
Brightness level	2	2	2	2	2	2
Built-up	2	2	2	2	2	2
Colour shade	V.LYELLOW	L.YELLOW	YELLOW	V.L.YELLOW	L.YELLOW	YELLOW
Wash fastness	2	3	2	2	2	2
Light fastness	-	-	4	-	-	3

Dye E: From Table 1, it can be seen that dye E gave poor hues on both the polyester and nylon fabrics. It can be seen from table 6 that both the physical properties and the fastness properties were relatively poor on both fabrics. This can be attributed to the low boiling point of the dye as stated earlier. In general dye E is noth suitable for dyeing both polyester and nylon fabrics.

By and large, all the fastness properties shown in the Table are interrelated since they depend, among other things, on the rate of diffusion of the dye in the fabric. This rate is a function of the geometry of the dye molecule. The concentration of dye in the fabric appeared to be the most influential factor in the fastness of the dyeings.

In attempting to trace relationships between chemical structure and light fastness, it is important to appreciate that there is no absolute value for the light fastness of a dye; the value obtained for a given colourant in any fading test depends on many factors, the most important of which are: concentration and/or degree of aggregation of the dye within the fabric; the nature of the fabric in which it is dispersed; characteristics of the incident radiation and molecular structure (Otutu, 2013).

The dyeing showed good to excellent light fastness properties when subjected to light fastness test and moderate to good wash fastness properties for most of the fabrics except dye E. Generally these dyes are highly suitable in application where light fastness is of much importance than light fastness.

CONCLUSION

Generally, these disperse dyes have shown greater substantivity with better light and washing fastness grade for polyester fibres than for polyamide.. The nylon polymer system is highly crystalline and hence, very hydrophobic.

Therefore, only limited range of disperse dyes have substantivity for the fabric. A remarkable degree of levelness after washing indicates good penetration of these dyes into the fabrics.

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