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Studies on the Dyeing Of Wool and Nylon Fabrics with Some Acid Dyes

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Abstract : *Wool and nylon fabrics were dyed using four different types of acid dyes of various colours i.e Lugani 101 (black), brown 3RG, nylomine (navy blue), methyl orange. Generally both wool and nylon fabrics exhibited higher percentage exhaustion. Relatively, nylon showed higher percentage exhaustion compared to wool. Also the dyed wool and nylon fabrics possess good fastness towards bleaching rubbing, pressing and perspiration but poor fastness to higher and washing.*
Keywords – *Acid dyes, exhaustion, fastness, nylon, wool,*

I. INTRODUCTION

Acid dyes are primary organic acids, usually available to the dyer in the form of salts. They are generally applied to fibre from solutions containing sulphuric, formic or acetic acids. However, majority of them are sodium salts of aromatic suphonic acids (RSO_3Na) but there are a few containing carboxylic groups. Most acid dyestuffs acquire their acidity from the present of sulphonic acid groups ($–SO_3$) or nitro ($–NO_2$) groups in the molecule [1]. Acid dyes being water-soluble anionic dyes are applied primarily to nitrogenous fibers such as wool, silk and nylon, all of which contain basic groups. They provide a complete colour range, varying from yellow to back, many of the being very bright [2].

Wool is the protein fibers obtained from the fibrous covering of sheep. Among the fibres used through ages to clothe man, wool occupies a unique position. However to provide the finest quality wool for the present day consumer, production is carefully and scientifically controlled. The finest quality wool is obtained from the merino, a breed that originated in Spain. The animal is small bodied, with many long, loose folds of skin. The fibre is fine and of high quality [3].

The coined word "nylon" is now an acceptable generic term for a group of synthetic polyamide fibres. The nylon fibres are long chain polymers with recurring amide (–CONH–) groups as an integral part of the main chain and so exhibits somewhat similar properties to proteins which are long chain polypeptides [4]. The nylons owe their existence to the genius of Wallace Carothers, research chemist heading a program of polymer research initiated by E. I Dupont de Nemours and Co in 1928. The research led to the introduction of the first commercial nylon, designated nylon 6.6 based on the number of carbon atoms in each of the reacting monomer [4].

Moreover, various reports are available in the literature on dyeing of wool and nylon with acid dyes the reason being that, acid dyes are used on fibres with cationic sites [5]. Though both wool and nylon can be dyed with reactive dyes, selected direct dyes and metal complex dyes, the present study intends to study the dyeing of wool and nylon fabrics with some acid dyes (Lugani 101 Brown 3RG, nylonmine and methylorange) with a view to assess and compare the fastness properties of the dyed fabrics towards various agencies which may likely provide an idea for a more compatible dye to be use for dyeing wool and nylon fabrics for economical dyeing as well as anticipated fastness properties that may be required by both local and commercial dyers [6].

II Material and Methods

All glasswares used were well washed with a detergent, rinsed with distilled water and dried in an over before use. Weighing was carried out on digital balance model, AB54 to four decimal places. Chemicals of analytical grade purity were used. The four different acid dyes were kindly supplied by African Textile Mills in Kano State, Nigeria and are of higher purity. Fastness properties as well as absorbance measurements were performed in African Textile Mills laboratory using standard equipments.

2.1. Scouring

3.5g of the fabrics wet with distilled water and soaked in a bath containing 0.8% Wanklin soap solution using liquor ratio 30:1. The mixture was heated to boil with continuous stirring for 1 hour at a temperature of 60^oC. The fabrics were then rinsed with water and allowed to dry [7,8].

2.2. Bleaching

1g of wool fabric was immersed in a solution containing 10cm^3 of 30% hydrogen peroxide (H_2O_2), 6cm^3 of 10% mgSO_4 and 100cm^3 of water. The fabric was then rinsed with water and allowed to dry [8].

2.3. Determination of λmax

0.01g each the four dyes was dissolved separately in 1 litre of distilled water. The absorbance of the dye solutions was then measured at varying wavelengths between 400 – 700nm at an interval of 10nm.

2.4. Calibration curve

The calibration curve for each dye was obtained by taking the absorbance at different concentrations of the dye solutions at their respective λmax. The range of concentrations used were 0.01g/litre, 0.005g/litre, 0.0033g/litre, 0.0025glitre, 0.00166g/litre,0.00143g/litre, 0.00125g/litre,0.00111g/litre and 0.01g/litre. Absorbance was then plotted against concentration (g/litre).

2.5. Dyeing of wool

The recipe used were: 3.5g fabric, liquor ratio (100:1) volume of dye (50cm^3) and volume of Glaubers salt (15cm^3). The concentrations of the stock solutions used were: Dye solution 1%, Glaubers salt 10% and H_2SO_4 99%. Simple laboratory methods of dyeing were adopted in dyeing the wool fabric with acid dyes as follows: 3.5g of wool fabric was immersed in the dye bath containing the above recipe and was stirred for 15miutes. The dye bath was heated to 90^{o}C for over 30 minutes with 10cm^3 of the sodium sulphate added after 15minutes, the remaining 5cm^3 was added at 90^{o}C. The temperature was maintained for another 60 minutes with stirring [2,9].

2.6. Dyeing of Nylon

The recipe used were: 3.5g fabric, liquor ratio (100:1) volume of dye (50cm^3), volume of hexamethylenediammine (10cm^3) and volume of ammonium acetate (10cm^3). The concentrations of the stock solution used were: 1% Dye solution, 3% ammonium acetate and 1% hexamethylene diammine. 10cm^3 of hexamethylene diammine and 10cm^3 of ammonium acetate were mixed and pH raised to 6.5 and the temperature was also gradually raised to 98^{o}C. 50cm^3 of 1% dye solution was then added to the dye bath. The fabric was then immersed in the dye solution and dyeing was carried out for 45 minutes. The fabric was then removed, rinsed and allowed to dry [2,10].

2.7. Soaping

3.5g of the dyed wool fabric was immersed in 25cm^3 of 2g/litre detergent solution and stirred continuously for 30 minutes at room temperature. The fabric was then removed, rinsed and allowed to dry.

III Colour Fastness Tests

3.1. Fastness to washing

The dyed specimens of dimension 5cm X 4cm each were placed between two pieces of undyed cotton fabric of the same dimension. The three pieces attached to each were held together by stitching round the edges to make a composite specimen. The specimen was placed in the wash liquor containing 25cm^3 of 2g/litre detergent solution, heated for 30 minutes at 60^{o}C. The composite specimen were then removed, thoroughly rinsed, opened and air-dried. The change in colour and the staining of the adjacent undyed fabric were assessed using the grey scale [11].

3.2. Fastness to bleaching

The dyed wool and nylon fabrics were cut into 5cm X 4cm pieces, placed between two pieces of undyed white fabric and stitched together round the edges to make a composite specimen. Each of the specimen was treated with 25cm^3 of 30% hydrogen peroxide. They were then removed, rinsed and air dried. The dyed fabric was detached from the undyed one. The change in colour and degree of staining of the undyed material were assessed using the appropriate grey scale[12].

3.3. Fastness to dry pressing

This was carried out by positioning 5cm X 4cm dyed fabric on a piece of dried white cloth of the same size and then pressed with a hot pressing iron for 20 seconds. The change in colour of the dyed material and the degree of staining of the undyed cloth were assessed using grey scale

3.4. Fastness to damp pressing
The damp pressing was carried out by placing the dyed fabric (5cm X 4cm) between the dried white cloth and a wet white cloth of the same size. The wet white cloth was placed on top white the dried white cloth was placed below. They were then pressed together for 20 seconds. The change in colour of the dyed material and the degree of staining of the white cloth were assessed using grey scale.

3.5. Fastness to rubbing
The dyed fabrics in contact with undyed fabric were pinned together (size, 5cm X 4cm). The two were rubbed several times together by hand. The change in colour and degree of staining of the undyed fabric was assessed using the appropriate grey scale.

3.6. Fastness to light
Strips of the dyed fabric and the blue wool standard were cut and mounted on a cardboard paper and half portions of the specimens were covered to block the source of light from getting to that portion. The specimens were exposed to artificial light source in a fadeometer instrument for two weeks. Eight Blue Wool Standards were also exposed simultaneously with the specimens for the same period. The specimens were then removed and the extents of their fading were assessed in comparison with the blue wool standard.

3.7. Fastness to perspiration
The perspiration fastness test required two different solutions i.e the acidic and the alkaline perspiration solutions. The test was carried out using composite specimen which was prepared as described previously. The composite specimens were immersed separately in alkaline and acidic solutions using liquor ratio of 20:1. The specimens were left in the solutions for 30 minutes at room temperature after which the specimens were brought out, drained and placed in between two glass slides for four hours. They were then removed and dried. The colour change of the dyed fabrics and degree of staining of the adjacent white fabrics were assessed using a grey scale.

1V Results And Discussions

4.1 Purification of fabrics, Determination of λmax and Preparation of Calibration Curve
Scouring and bleaching are performed on fabrics before dyeing in order to remove natural fats, waxes, proteins, dirt, oil, impurities and colouring matter. The scored fabric was found to be cleaner with higher rates of dye absorption and equally, the bleached fabric (wool) becomes white while the appearance of nylon fabric after bleaching remains the same as it were before bleaching i.e there was no visible change after bleaching of the nylon fabrics. This result suggest that wool being a natural fibre contains natural colouring matters or impurities which can only be removed by bleaching in contrast to nylon which is man – made fibre, devoid of coloured impurities hence can be dyed without further purification.
The λmax of the four dyes are presented in Table 1.

Table 1: λmax values for dye A, B, C, and D

Dye	Name of dye	λmax (nm)
A	Lugani 101	600nm
B	Methyl orange	501nm
C	Brown 3RG	440nm
D	Nylomine	400nm

The λmax values obtained for the four dyes varied from 600nm for dye A to 400nm for dye D. the difference in the λmax values for the dyes may be due to the fact that the dyes have different colours and different chromophore constitution; hence they will absorb radiation selectively from the visible region (4).

Similarly, the absorbance values of different concentrations of dyes A, B, C and D at various λmax are presented in Table 2.

Table 2: Absorbance value at different concentrations of dye A, B, C, and D at their various λmax

	Absorbances			
Concentration of dyes (g/L)	**Dye A**	**Dye B**	**Dye C**	**Dye D**
0.01	1.268	1.82	0.843	0.018
0.005	0.683	1.644	0.451	0.018
0.0033	0.440	1.361	0.317	0.016
0.0025	0.322	1.034	0.234	0.014
0.002	0.262	0.859	0.180	0.012
0.0016	0218	0.729	0.150	0.011
0.00143	0.179	0.670	0.128	0.010
0.00125	0.161	0.565	0.113	0.009
0.00111	0.136	0.470	0.100	0.006
0.001	0.122	0.355	0.09	0.005

4.2. Dyeing
At the end of the dyeing process, using the exhaustion method for the two fabrics, dyed fabrics of different depth of shades were obtained with wool fabric having higher depth of shades as evident from visual assessment of the dyed materials.

4.3. Percentage exhaustion (%E)
This is the amount of dye uptake by the fabric was calculated using the equation:

$$\% E = \frac{C_i - C_f}{C_i} \times 100$$

Where C_i = concentration of the dye in the dyebath before dyeing
C_f = concentration of dye in the dyebath after dyeing.
The results for percentage exhaustion of dyes on wool and nylon are presented in table 3 and 4 respectively.

Table 3: Percentage exhaustion (%E) of dyes on wool

Dye	C_i	C_f	% E
A	0.01	0.0027	73%
B	0.01	0.006	94%
C	0.01	0.0022	78%
D	0.01	0.0038	62%

The percentage exhaustion of dyes varies from 89% to 50% for wool and 62% to 94% for nylon fabrics. Dye B has the highest percentage exhaustion for both wool and nylon (i.e 89% for wool and 94% for nylon). This may be due to its relatively low molecular size and also low anion affinity which enable it to exhibit good leveling and migration properties.

Generally it can be seen from the tales (3 and 4) that acid dyes exhibit higher affinity on nylon and wool. The substantivity for acid dyes derives mainly from the presence in their structure of terminal amino groups, and to some extent also, of amide links in the polymer chain. The higher parentage exhaustion of these dyes may be due to the presence of large number of amino end groups (AEG) on nylon fibre.

However, the mechanisms of dyeing nylon and wool with acid dyes are shown in figure 1 and 2. From figure 1, it can be seen that dye attachment onto nylon is by ionic or salt links.

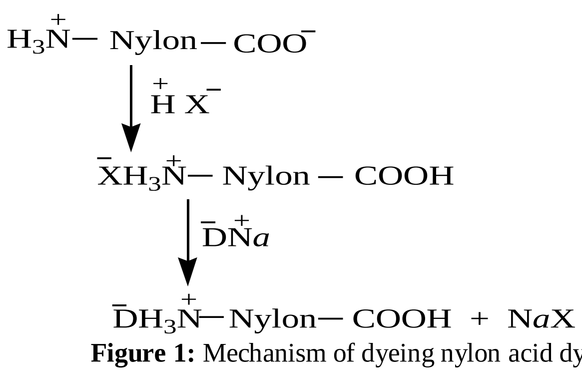

Figure 1: Mechanism of dyeing nylon acid dyes

A similar mechanism for wool dyeing with acid dyes (Figure 2) reveals that dye attachment onto wool is by ionic or salt links.

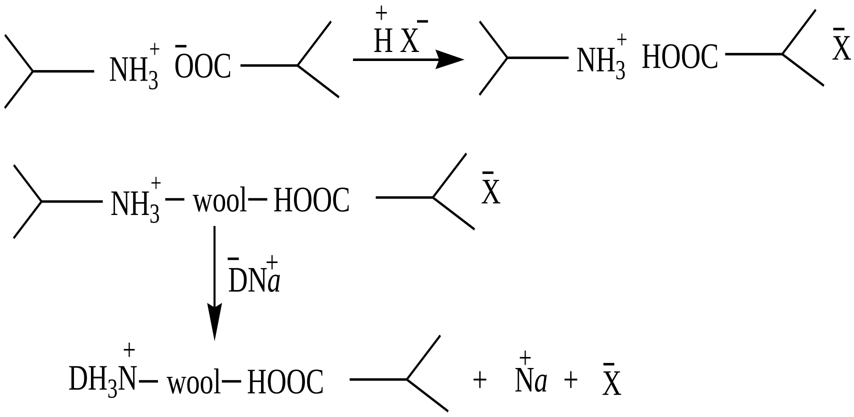

Figure 2: Mechanism of dyeing wool acid dyes

4.5. Fastness Properties of the dyed Nylon and Wool fabrics

At the end of the soaping process, the dyed materials were found to be brighter when compared to their appearance before soaping.

The results of these fastness tests are shown in Table 7, 8, 9, 10 and 11. Tables 5 and 6 describe the normal fastness grades (washing, pressing, bleaching, perspiration etc) and light fastness grades respectively [13]

Table 5. Description of normal fastness grades

Fastness grade	Shade change of tested sample	Fastness	Staining of adjacent white sample
Grade 5	No change	Excellent	No staining
Grade 4	Slight loss in depth	Good	Very slight staining
Grade 3	Appreciable loss	Fair	Moderate staining
Grade 2	Significant loss	Poor	Significant staining
Grade 1	Great loss in depth	Very poor	Deep staining

Table 6. Description of the light fastness grades

Fastness Grade	Degree of fading	Light fastness
Grade 8	None	Outstanding
Grade 7	Very, very slight	Excellent
Grade 6	Slight	Very good
Grade 5	Moderate	Good
Grade 4	Appreciable	Moderate
Grade 3	Significant	Fair
Grade 2	Extensive	Poor
Grade 1	Very extensive	Very poor

Table 7: Fastness rating for the degree of staining of adjacent white material by dyed wool fabric.

Dye	Fastness to bleaching	Fastness to washing	Rubbring	Fastness pressing		Perspiration	
				Dry	Damp	Alkaline	Acidic
A	4 – 5	3	4	4	4	4	4
B	3	3 – 4	3	4	3	4	3
C	3 – 4	3	4	4	3	3	3
D	3 – 4	3 – 4	4	5	4	4	4

Table 8: Colour fastness rating for the wool fabrics

Dye	Fastness to bleaching	Fastness to washing	Fastness to Rubbing	Fastness to pressing		Fastness to Perspiration	
				Dry	Damp	Alkaline	Acid
A	5	2	4	5	4	4	4
B	4	1	4	5	3	4	3
C	4	2	4	5	3	3	3
D	4	2	4	5	4	4	4

Table 9: Fastness rating for the degree of staining of adjacent white fabric by dyed nylon fabric
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Dye	Fastness to bleaching	Fastness to washing	Fastness to Rubbing	Fastness to pressing		Fastness to Perspiration	
				Dry	Damp	Alkaline	Acidic
A	4 – 5	3	4	4	4	4	3
B	3	2 – 3	4	4	3	3	3
C	4 – 5	4 – 5	4	5	3	3	4
D	4 – 5	4	3 – 4	5	4	4	4 – 5

Table 10: Colour change of dyed nylon fabric after washing, bleaching, rubbing and pressing.

Dye	Fastness to bleaching	Fastness to washing	Fastness to Rubbing	Fastness to pressing		Fastness to Perspiration	
				Dry	Damp	Alkaline	Acidic
A	4	1	4	5	4	4	4
B	4	2	4	5	4	3	4
C	4	1	5	5	5	3	5
D	5	1	5	5	5	4	5

Table 11: Light fastness rating of dyed wool and nylon fabrics.

Dye	Rating	
	Wool	Nylon
A	5	4
B	3	3
C	7	3
D	7	4

It is evident from the result of the assessments presented on Table 7 – 11 that the nylon and wool fabric exhibited good to excellent fastness test to bleaching, rubbing, pressing and perspiration but poor fastness to light and washing.

However, the good fastness to rubbing obtained indicates that there was no staining of other fabric rubbed against the dyed fabric. Also the test for dry and damp fastness to pressing showed excellent and good ratings respectively, thus both dry and damp pressing are recommended for nylon and wool fabrics when dyed with acid dyes. Another positive results obtained were good fastness to bleaching and this implies that bleaching agents do not have adverse effects on the dyed fabrics.

V. Conclusion and Recommendation.

From the results of the study it may be observed that acid dyes have good substantively and high exhaustion for both nylon and wool fabrics, even though nylon has higher percentage exhaustion, which may be due to its open structure. Nylon however is less thick fabric than wool. Both nylon and wool fabrics showed good colour fastness properties to bleaching agents, pressing (dry and damp) and perspiration but poor fastness to high and washing.

However, it may be concluded that dye B may be more suitable for dyeing nylon and wool be more suitable for dyeing nylon and wool fabrics based on the results obtained and can be utilize by both local and commercial dyers. The draw backs found (poor light and wash fastness) may be overcome by suitable after treatments hence research efforts should be tilted towards enhancement of the properties of acid dyed wool and nylon fabrics through after treatments.

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