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Improvement of the UV-protective Properties of Cotton Fabric Dyed with Polyfunctional Reactive Dye Modified from Reactive Red

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ABSTRACT

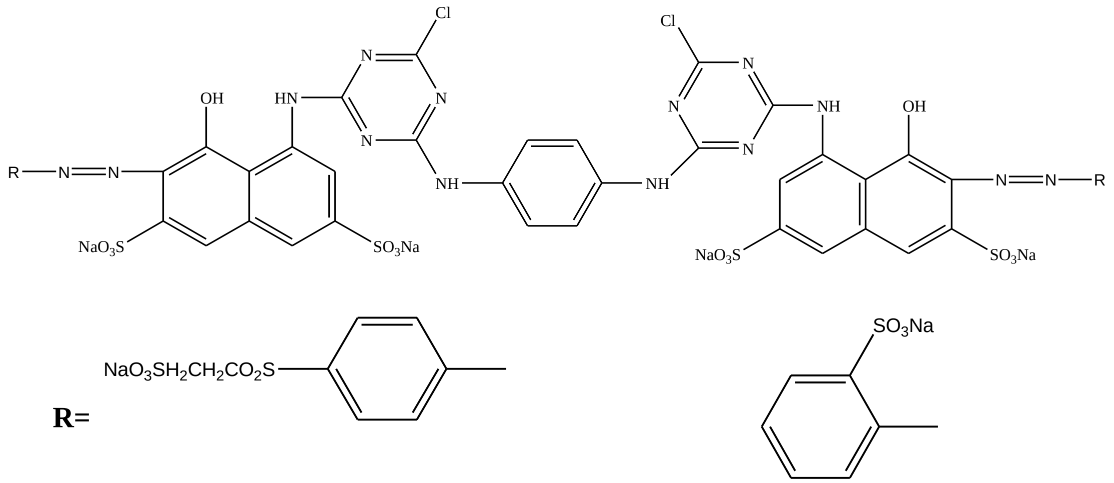
Synthesis and characterization of polyfunctional reactive dye having modified structure from CI Reactive Red 120 were studied. The modification was carried out by replacing the two orthanilic acid moieties presented in the commercial reactive dye with two 1-aminobenzene-4-β-sulphatoethylsulphone moieties. Optimum exhaustion and total fixation for both dyes on cotton fabric were achieved at 80 g/l sodium sulphate, 15 g/l sodium carbonate for the synthesized polyfunctional dye, 20 g/l sodium carbonate for the commercial dye at 80 ℃ for both dyes. The synthesized polyfunctional dye exceeds by about 9% in its total fixation values than that of the commercial reactive dye. The ultraviolet (UV) protective properties for both reactive dyes were examined at different dye concentrations. The samples dyed with the synthesized polyfunctional dye achieved ultraviolet protection factor (UPF) values exceed by about 19-22% than those samples dyed with the commercial dye. The synthesized polyfunctional dye exhibited higher fastness properties than the commercial dye.

Keywords: Polyfunctional reactive dye, UPF, Dyeing of cotton, Exhaustion, Total fixation

1. Introduction

In the last decades, the increased awareness of sunlight harmful effects on human skin, made the scientists to think for different parameters to avoid skin exposure to the harmful ultraviolet radiation (UVR), UV-B (280-320 nm) and UV-A (320-400 nm) radiations (Chakraborty, Sharma, & Gautam, 2014). The use of textile garments is among the most important parameters, but the UV protection efficiency for all types of textiles is controlled by different factors; nature of fibers (Schuicrer, 1997; Djam, Rosinskaja, Kizil, & Weinberg, 2001), fabric construction (Davis, Capjack, Kerr, & Fedosejevs, 1997; Algaba, Pepió, & Riva, 2008; Gabrijelčič, Urbas, Sluga, & Dimitrovski, 2009), moisture content of the fabric (Bajaj, Kothari, & Ghosh, 2000), stretching (Bajaj, Kothari, & Ghosh, 2000; Akgun, Becerir, & Alpay. 2010), finishes (Abrahart, 1977; Achwal, 2000; Eckhardt, & Rohwer, 2000; Holme, 2003), and dyes. In general coloration can considerably improve the UV protection of fabrics (Rosinskaya, Djam, Weinberg, & Kizil 2003; Hustvedt, & Crews, 2005).

The UV protection efficiency of the textile materials is greatly influenced by the color of the dyes or pigments used. Darker colors like (black, navy, dark red) absorb UVR strongly more than the light colors (Srinivasan, & Gatewood, 2000; Hunt, 2003). Also the color depth has an essential role in maximizing fabric UV protection. Generally, the UPF of fabrics increases by increasing the dye concentrations (Wilson, Gies, Niven, McLennan, & Bevin, 2008). The UV protective properties of different dye class types were extensively studied, like natural dyes (Sarkar, 2004; Gupta, Jain, & Panwar, 2005; Kim, 2006; Grifoni, Bacci, Zipoli, Carreras, Baronti, & Sabatini, 2009; Yadav, Karolia, & Mairal, 2009; Grifoni, Bacci, Zipoli, Albanese, & Sabatini, 2011; Mongkholrattanasit, Kryštůfek, Wiener, & Viková, 2011; Vidhya, & Rekha, 2012; Hou, X. Chen, Cheng, Xu, L. Chen, & Yang, 2013; Gawish, Farouk, Ramadan, Mashaly, & Helmy, 2016), direct dyes (Veatch, & Gatewood, 2002; Kan, & Au, 2015; Riva, Algaba, Pepió, & Prieto, 2009), disperse and acid dyes (Veatch, & Gatewood, 2002), and reactive dyes (Veatch, & Gatewood, 2002; Paluszkiewicz , Czajkowski, Kaźmierska, & Stolarski, 2005; Czajkowski, & Paluszkiewicz, 2008; Dubrovski, & Brezocnik, 2009; He, Gong, Freeman, Jian, Chen, & Zhao, 2010). However, the considerable role of dyes in UV protection is related to their absorption position and intensity in the UV spectrum. This is greatly depending on chemical structure of dyes rather than the dye class (Veatch, & Gatewood, 2002; Wong, Lam, Kan, & Postle, 2016). On the other hand, reactive dyes have the merit of maintaining UV protection for prolonged time compared to any other dye class, due to the presence of one or more reactive groups which could form covalent bonds with the active site in the fabric. Reactive dyes are classified according to the number of reactive groups present in the dye structure to monofunctional, bifunctional (which classified to homobifunctional and hetero-bifunctional) and polyfunctional reactive dyes. It is well known that the number and the type of reactive group are the main factors affecting on the dyeing properties of the reactive dyes, additionally these factors also could affect the finishing properties accepted by the fabrics dyed with reactive dyes, like UV protective properties. To emphasis this meaning, we intend to study the essential role of the number and type of reactive groups in reactive dyes on the UV protective properties of cotton fabric. To achieve this goal, we study the dyeing and UV protective properties of homobifunctional commercial reactive dye (C.I. Reactive Red 120), that contain bis(monochlorotriazine) (MCT) reactive groups, compared with polyfunctional reactive dye modified from C.I. Reactive Red 120 by replacing the two orthanilic acid moieties of the commercial dye by two 1-aminobenzene-4-β-sulphatoethylsulphone moieties in the modified polyfunctional reactive dye, previously synthesized (Matyjas, & Rybicki, 2003).



Polyfunctional reactive dye 1

(C.I. Reactive Red 120) dye 2

2. Experimental

2.1. Materials and chemicals

Mill-scoured and bleached cotton fabric, 125 g/m^2 (fabric density: number of warp yarns = 78 per inch, number of weft yarns = 66 per inch) was obtained from Misr company for spinning and weaving El-Mahala El-Kobra, Egypt. Before dying, the fabric was treated with a solution containing 3 g/l non-ionic detergent (Hostapal CV, Hoechst) and 5 g/l sodium carbonate at liquor ratio 1:50 at boiling for 4 h, thoroughly washed in water and dried at room temperature.

Cyanuric chloride was obtained from Aldrich.1-Aminobenzene-4-β-sulphatoethylsulphone was obtained from Amar Impex, Mumbai, India. All other chemicals and solvents used in this study were of laboratory reagent grade.

CI Reactive Red 120 dye 2 was obtained from DyStar. Thin-layer chromatography (TLC) was performed by a Kieselgel 60 F254 (Merck, Darmstadt, Germany), to follow the reaction progress and the purity of the synthesised dye.

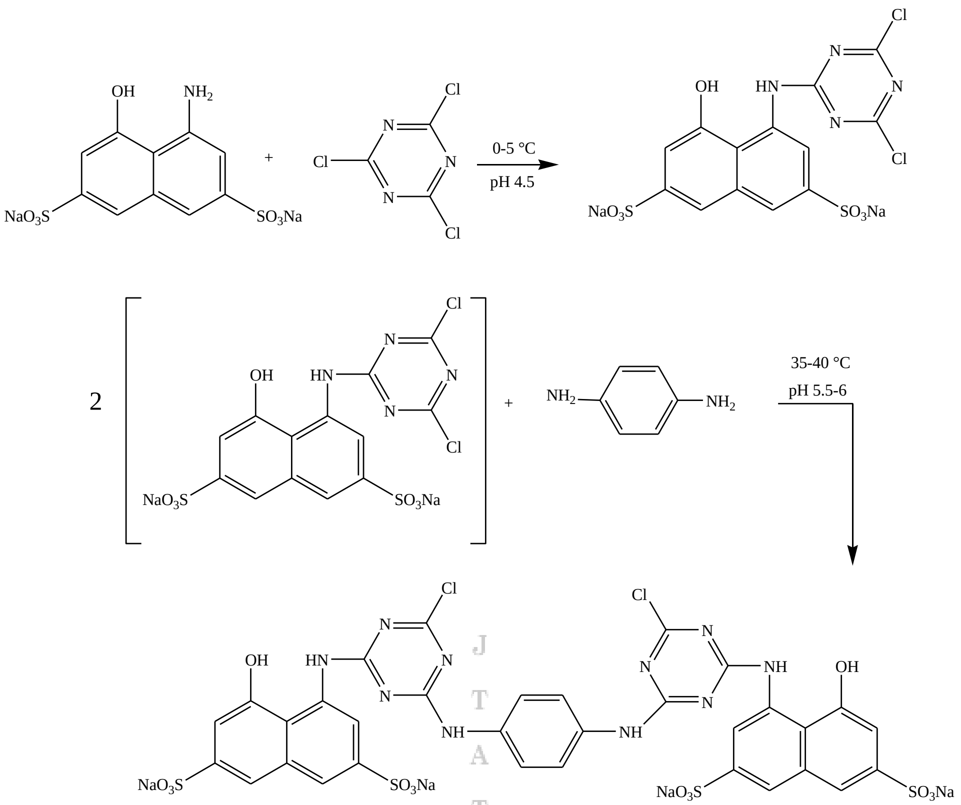
2.2. Methods

2.2.1. Synthesis of the polyfunctional reactive dye 1

The synthesis of the polyfunctional reactive dye **1** was carried out in two steps as follows:

The first step: The preparation of the coupling component (scheme 1):

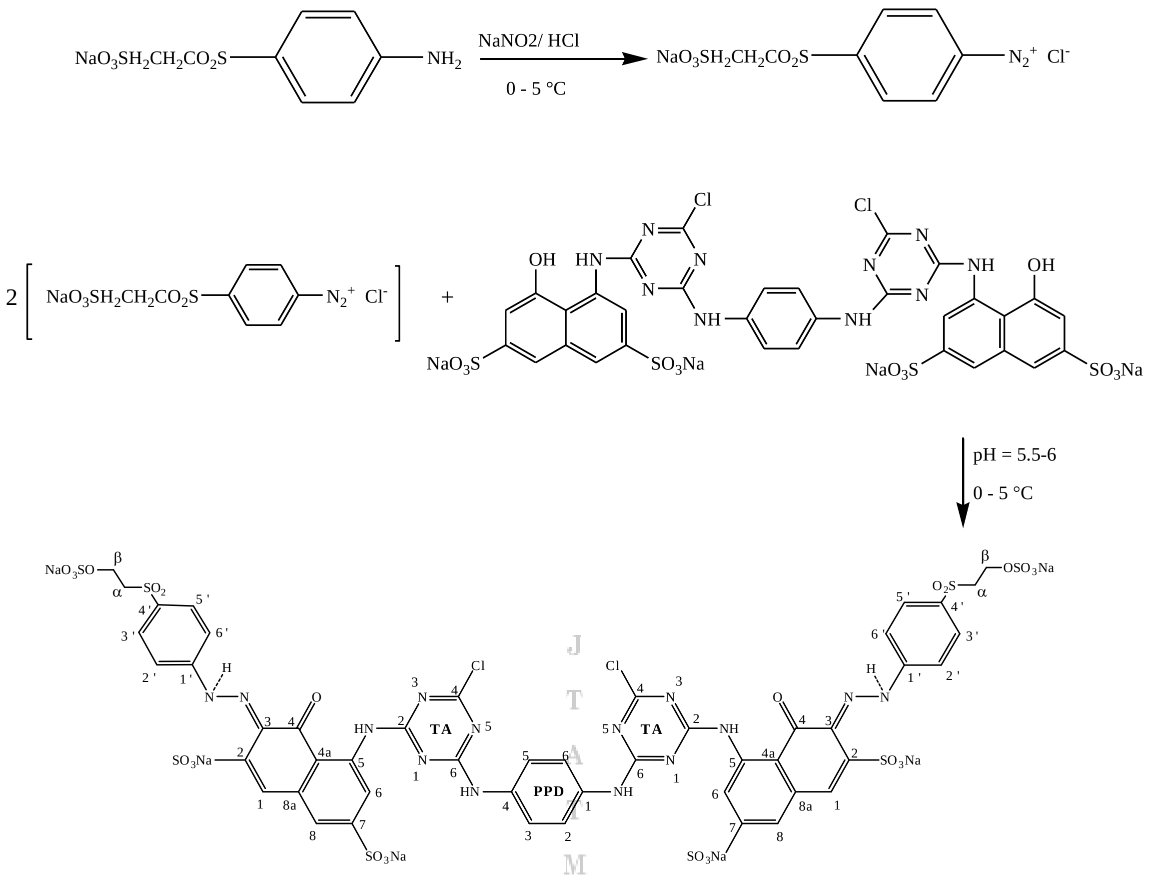
The coupling component was initially prepared by dissolving cyanuric chloride (7.76 g; 0.04 mol; 95%) in acetone, then poured on ice. The H-acid solution (15.97 g; 0.04 mol; 80%) adjusted at pH = 7 was then added over 30 min and the reaction mixture was stirred at 0–5 °C for 4 h while controlling the pH at 4.5 using 2 M aqueous solution of sodium carbonate and the progress of the reaction was monitored by TLC. After finishing the first condensation stage, the solution of *p*-phenlene diamine (2.25 g; 0.02 mol; 96 %) in acetone, was then poured over 30 min to the reaction mixture and stirred at 35-40 °C, pH 5.5–6 for 5 h, the reaction was monitored by TLC, the precipitated compound was filtered off and dried in a vacuum oven at 30 °C.



Scheme 1

The second step: The coupling reaction (scheme 2):

The solution of coupling component adjusted at pH 7 (10.17 g; 0.01 mol; 95%) was coupled by ratio 1:2 with the diazonium salt of 1-aminobenzene-4-β-sulphatoethylsulphone (5.92 g; 0.02 mol; 95%) which was diazotized as previously described (Lewis, Renfrew, & Siddique, 2000). The coupling reaction was carried out at 0 -5 °C, pH 5.5-6 using 2 M aqueous solution of sodium carbonate and followed by TLC. The produced dye was precipitated by adding ethanol absolute, filtered off and dried in a vacuum oven at 30°C. The dye had a maximum absorption λ_{max} (H_2O) = 514.4 nm.



Scheme 2

The dye structure of the polyfunctional reactive dye **1** ($C_{48}H_{32}N_{14}O_{24}S_8Na_6Cl_2$) was confirmed from the following results:

Calc. (%): C, 34.85; H, 1.95; N, 11.85; S, 15.51. Found (%): C, 34.9; H, 1.97; N, 11.82; S, 15.53.

Sodium 2-((4-((E)-(8-((4-chloro-6-((4-((4-chloro-6-((8-hydroxy-3,6-disulfonato-7-((E)-(4-((2-(sulfonatooxy)ethyl)sulfonyl)phenyl)diazenyl)naphthalen-1-yl)amino)-1,3,5-triazin-2-yl)amino)phenyl)amino)-1,3,5-triazin-2-yl)amino)-1-hydroxy-3,6-disulfonatonaphthalen-2-yl)diazenyl)phenyl)sulfonyl) ethyl sulfate

IR, (n/cm-1): 1127.19, 1040.41 and 985.447 cm-1 (OSO_3H), 1190.83 (–SO_2–), 1481.06 (-N=N-), 2967.91 (aliphatic CH), 3408.57 (aromatic OH). ^{1}H NMR (400 MHz, DMSO-*d6*): ppm 15.07 (2H, br s, 2x H-bonded -OHs), 9.14, 8.89 (2H each, br s each, 4 x –NH), 8.09–7.45 (18H, m, aromatic-H, s), 3.99 (4H, t, *J* = 6.2 Hz, 2x –CH_2–b), 3.67 (4H, t, *J* = 6.2 Hz, 2x –CH_2–a); 13C NMR (100 MHz, DMSO-*d6*): ppm 181.3 (C-4), 168.8 (TA-C-2), 164.5 (TA-C-4), 162.8 (TA-C-6), 155.7 (C-7), 154.2 (C-2), 147.3 (C-1'), 143.9 (C-5), 135.5 (C-8a), 130.1 (C-3), 129.9 (PPD-C-1,4), 129.8 (C-4', 3'/5'), 123.3 (C-2'/6'), 121.2 (C-1), 119.2 (C-8), 118.2 (PPD-C-2,3,4,6), 116.9 (C-4a), 116.2 (C-6), 59.7 (CH2-β), 55.3 (CH2-a); TA = Triazin; PPD = *p*-Phenylenediamine.

2.2.2. Dye Purification

For convenient dyeing and chemical investigation, it was necessary to purify the polyfunctional dye **1** and the commercial reactive dye **2** (Guo, Petit-Ramel, Gauthier, Chabert, & Jacquet, 1993). The purification was done by dissolving the dyes in dimethylsulphoxide at 30°C. Inorganic impurities were eliminated by filtration and the dye solution was re-precipitated in nbutanol at room temperature. The dyes were filtered, washed with acetone and dried in a vacuum oven at 30°C.

2.2.3. Dyeing procedure

A series of dyeings on cotton fabric was produced using both dyes **1** and **2** at a liquor ratio 40:1 at various dye concentrations (1–4% owf). The dyeing was started at 40 ◦C, for 30 min, during this period 20, 40, 60 and/or 80 g/l sodium sulphate was added in two portions at an interval of 15 min. Then various amounts of sodium carbonate (5–25 g/l) were added portion wise while the temperature was raised to 60, 70 and/or 80 ◦C over 30 min. After which time, the dyeing was continued at the desired fixation temperature for a further 60 min unless otherwise specified. After dyeing, all the dyed samples were rinsed with water and air-dried.

2.3. Measurements

2.3.1. General

Infrared (IR) spectra were recorded on a Jasco FT/IR 4700. The transmittance between 400 and 4000 cm^{-1} was recorded. The NMR spectra were recorded on a Bruker High performance Digital FT-NMR Spectrometer Advance III: 400 MHz for ^{1}HNMR and 100 MHz for ^{13}CNMR; the chemical shift values are expressed in δ ppm and the *J* values are given in Hz for ^{1}HNMR. The UV/vis spectra were measured on a Shimadzu UV-2401PC UV/Vis spectrophotometer (Shimadzu, Japan). The UPF values were measured on JASCO V-750 UV-Visible spectrophotometer (United States).

2.3.2. Dye Exhaustion

For all dyeings, the dye exhaustion was measured by sampling the dye-bath before and after dyeing. The dye concentration (g/l) of the dye-bath was measured on Shimadzu UV-2401PC UV/vis spectrophotometer at λ_{max} for each dye. The percentage of dye-bath exhaustion (%E) was calculated using Eq. (1):

$$\%E = \left[1 - \left({C_2}/{C_1} \right)\right] \times 100 \qquad (1)$$

where C_1, C_2 are the concentrations of the dye-bath before and after dyeing, respectively.

2.3.3. Dye fixation

The dye fixation ratio (%F); the percentage of the exhausted dye chemically bound on the fiber, was measured by refluxing the dyed samples in 50% aqueous DMF (liquor ratio 20:1) for 10 min to extract the unfixed dye (Bredereck, & Schumacher, 1993). This procedure was repeated until the extract was clear. The concentration of the extract was then measured spectrophotometrically at λ_{max} and the percentage dye fixation ratio (%F) was calculated using Eq. (2):

$$\%F = \frac{\left(C_1 - C_2 - C_3\right)}{\left(C_1 - C_2\right)} \times 100 \qquad (2)$$

Where C_3 is the concentrations of extracted dye.

From the results of the dye-bath exhaustion (E) and dye fixation ratio (F), the total dye fixation (T), which is the percentage of the dye chemically bound relative to the total amount of dye used, was calculated for all dyeings using Eq. (3):

$$\%T = \frac{\left(\%E \times \%F\right)}{100} \qquad (3)$$

2.3.4. The ultraviolet protection factor (UPF)

UPF of the dyed samples was evaluated using AS/ NZS 4399:1996 test method, by cutting each specimen at least 5 x 5 cm place the specimen flush against the sample transmission port opening in the sphere.

The UVR transmittance of fabrics was measured over the UV spectrum (290–400 nm) with 5 nm intervals. The UPF was calculated by Equation (4) (Grifoni, Bacci, Zipoli, Carreras, Baronti, & Sabatini, 2009; Algaba, Pepió, & Riva, 2008).

$$\mathrm{UPF} = \frac{\sum_{290\mathrm{nm}}^{400\mathrm{nm}} E_{\lambda} \times S_{\lambda} \times \Delta\lambda}{\sum_{290\ \mathrm{nm}}^{400\ \mathrm{nm}} E_{\lambda} \times S_{\lambda} \times T_{\lambda} \times \Delta\lambda} \quad (4)$$

Where E_{λ} is CIE relative erythemal spectral effectiveness, S_{λ} is solar spectral irradiance, T_{λ} is spectral transmittance of the fabric, λ is wavelength in nm and $\Delta\lambda$ is the wavelength step in nm.

Fabrics with a UPF value in the range 15–24 are classified as having ‘‘Good UV Protection’’; when the UPF values are between 25 and 39 fabrics are classified as having ‘‘Very Good UV Protection’’ and ‘‘Excellent UV Protection’’ classification is used when the UPF is 40 or greater (Algaba, Pepió, & Riva, 2008).

3. Results and Discussion

3.1. Synthesis

3.1.1. Characterization of polyfunctional reactive dye 1

The successful synthesis of polyfunctional reactive dye was proved by recoding its elemental analysis and spectral data IR and NMR (^{1}H and ^{13}C).

3.1.1.1. *IR*

The IR spectra of the polyfunctional reactive dye showed the characteristic bands of 3408 indicating presence of aromatic–OH stretching vibration. This confirms the predomination of the azo tautomer of prepared reactive azo dye away from the polar solvent DMSO-d_6. The bands which appeared at 1481 is due to the stretching vibration of –N=N– group of the polyfunctional reactive dye. Three characteristics bands appeared at 1127, 1040 and 985 which indicate the presence of –SO_3- groups.

3.1.1.2. *^{1}H-NMR*

In ^{1}H NMR spectra, the most downfield proton (viz. H-bonded –NH) was assigned at about δ 15 ppm in of polyfunctional reactive dye, which is considered the first document for the predomination of hydrazone tautomer in DMSO rather than azo one (Lyčka, & Jirman, 1987). Concerning to the aromatic-Hs, it was appeared as a multiplet complex region at 8.0-7.5 ppm in the polyfunctional reactive dye. Moreover, the aliphatic protons was distinguished as aliphatic spin coupling system interpreted as A_2M_2–system of two triplets at 3.99 and 3.67 ppm, that was indicative for the presence of –CH_2CH_2– group in the structures of the polyfunctional reactive dye (see experimental data).

3.1.1.3. *^{13}C-NMR*

Further confirmation for the successful synthesis of polyfunctional reactive dye was concluded from the ^{13}C NMR spectra that showed the typical three resonances of the triazine moiety at about 169 (C-2), 165 (C-4) and 163 (C-6) in the polyfunctional reactive dye. The preparation of polyfunctional reactive dye was also documented from the characteristic two upfield signals of –CH_2CH_2- at 59.7 and 55.3 ppm. The predomination of the hydrazone form of the polyfunctional reactive dye in DMSO was further established by the assignment of the intrinsic ten signals of naphthalene moiety, particularly that of C_4=O and C_3=N at about 181 and 130 ppm along with C-7, C-2 and C-5 at about 156, 154 and 144, respectively.

3.2. Application

3.2.1 Effect of salt concentration

The salt concentration is one of the most important factors affects the dyeing behavior of reactive dyes. Dyeing of cotton fabric using 2% owf of the polyfunctional dye **1** and the commercial reactive dye **2** was studied at different salt concentrations (20, 40, 60 and 80g/l), and the results are given in Figure 1. The results clearly reveal that however, the optimum salt concentration for both dyes **1** and **2** achieved at 80 g/l, but on the other hand, the extent of exhaustion and total fixation for both dyes **1** and **2** slightly increases as salt concentration increases, this indicate that both dyes represent good substantivity even at low salt concentration. The polyfunctional reactive dye **1** exhibited higher total fixation values than the commercial dye **2**. This may be attributed to the presence of the two additional sulphatoethylsulphone (SES) reactive groups, which in turn increases the probability of dye-fiber interaction.

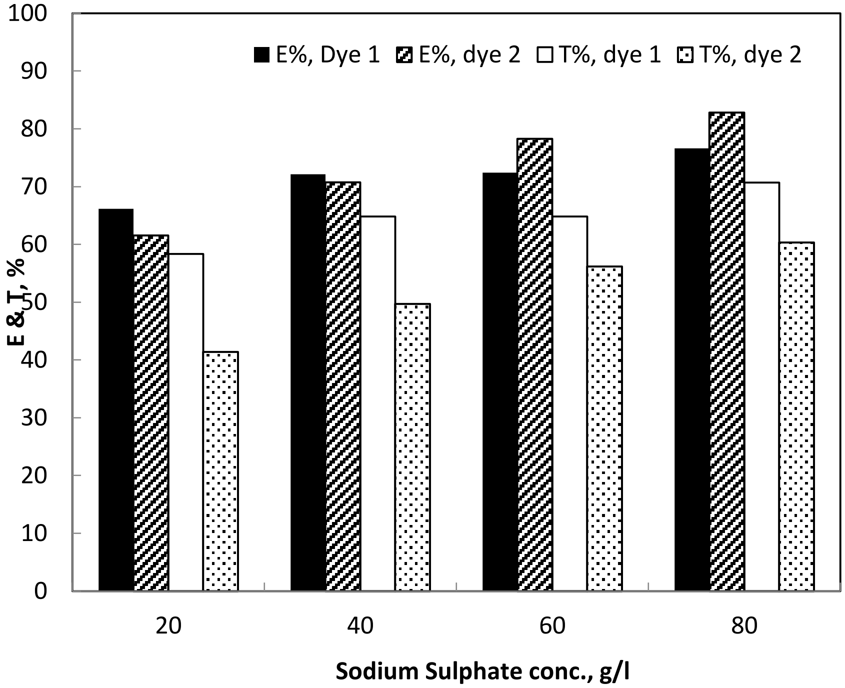


Figure 1: Extent of exhaustion (E%) and total fixation (T%) for polyfunctional reactive dye 1 and the commercial reactive dye 2 on cotton fabric at different salt concentrations.

3.2.2. Effect of alkali concentration and temperature on dye fixation

To study the effect of alkali concentration on the dyeing behavior of dyes 1 and 2, a series of dyeings was carried out using 2% owf dye concentration on cotton fabric firstly at the optimum neutral dyeing conditions of 80 g/l sodium sulphate at 40 °C for both dyes, then secondly at various sodium carbonate concentrations (5, 10, 15, 20 and 25 g/l), and examining the suitable fixation temperature at 60, 70 and/or 80 °C. The results are shown in Figures 2-4. The results clearly show that, the extent of exhaustion of the commercial reactive dye 2 is higher than that of polyfunctional reactive dye 1 at 60 °C fixation temperature, but the difference between them significantly decreased at higher fixation temperatures. On the other hand, the total fixation efficiency of the polyfunctional reactive dye 1 is higher than that of the commercial reactive dye 2 over the fixation temperatures examined, due to the presence of the two SES and two MCT reactive groups in the polyfunctional dye 1 compared to the two MCT reactive groups present in the commercial reactive dye 2.

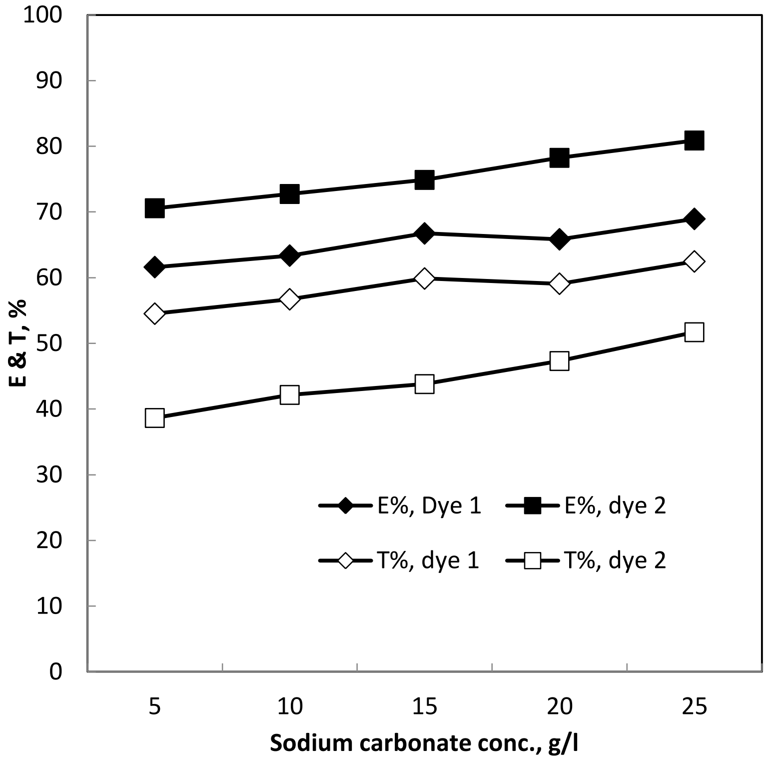


Figure 2: E% and T% for both polyfunctional reactive dye 1 and commercial reactive dye 2 on cotton fabric at different sodium carbonate concentrations at fixation temperature 60 °C

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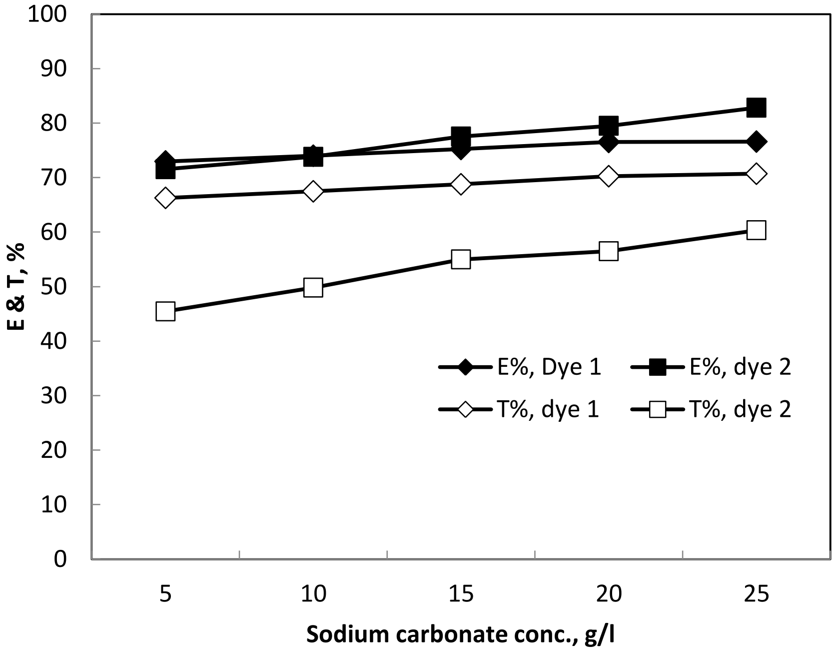

Figure 3: E% and T% for both polyfunctional reactive dye 1 and commercial reactive dye 2 on cotton fabric at different sodium carbonate concentrations at fixation temperature 70 °C.

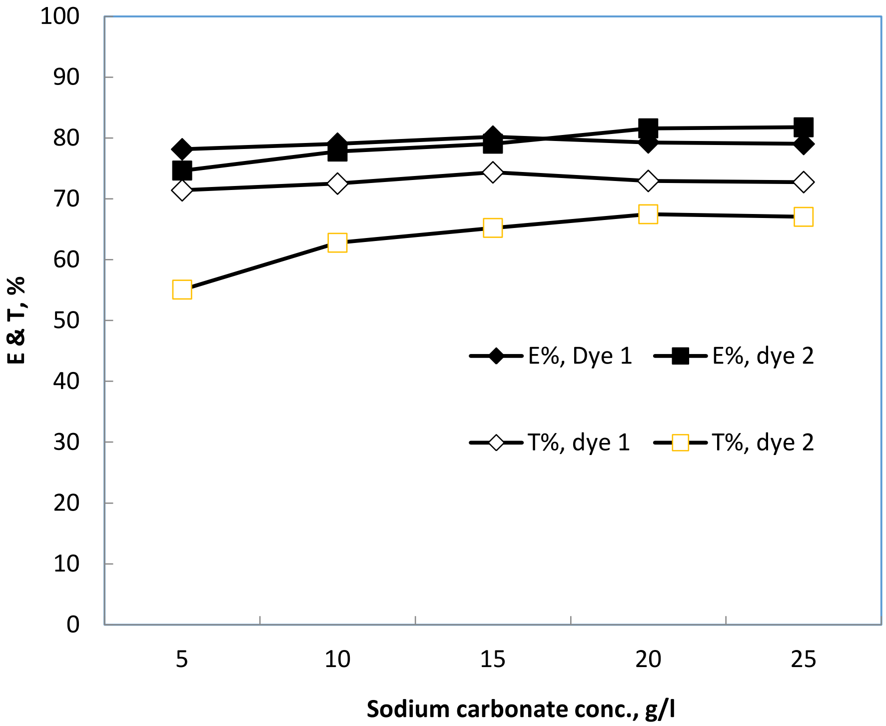

Figure 4: E% and T% for both polyfunctional reactive dye 1 and commercial reactive dye 2 on cotton fabric at different sodium carbonate concentrations at fixation temperature 80 °C.

3.2.3. Effect of dyeing time

The effect of dyeing time was examined using 2% owf dye concentration for both dyes at neutral dyeing conditions of 80 g/l sodium sulphate at 40 °C for both dyes, and optimum fixation conditions of 15 g/l sodium carbonate for dye 1 and 20 g/l for dye 2 at 80 °C for both dyes. The results presented in Figure 5 clearly show that both dyes achieve very near exhaustion values over the range of dyeing time, but the polyfunctional reactive dye 1 showed higher total fixation values than those of the commercial dye 2 over the range of the dyeing time, its total fixation values are exceed by about 9-17% compared to the total fixation values obtained by the commercial reactive dye 2.

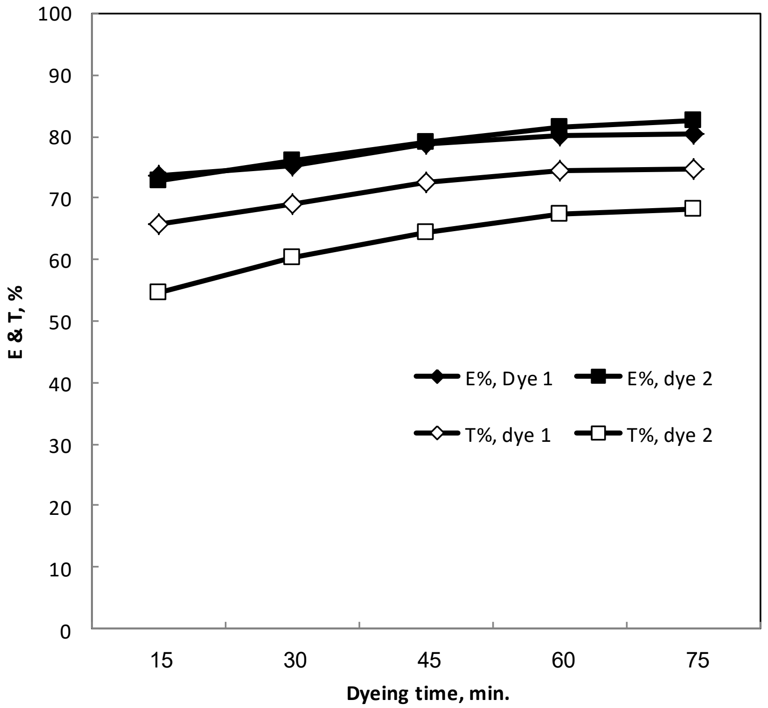

Figure 5: E% and T% of the polyfunctional reactive dye 1 and the commercial reactive dye 2 on cotton fabric at different fixation time.

3.2.4. Effect of dye concentration

After determining the optimum conditions for both dyes 1 and 2 at 80 g/l sodium sulphate for both dyes and 15 g/l sodium carbonate for the polyfunctional dye 1, 20 g/l sodium carbonate for commercial dye 2, at 80 °C fixation temperature and 60 min fixation time for both dyes. The study was extended at different dye concentrations and the results are given in Figure 6. From the results we can notice that the extents of exhaustion values for both dyes are approximately the same, but the polyfunctional reactive dye 1 secured higher total fixation values than those of the commercial reactive dye 2.

The extent of exhaustion and total fixation values of both dyes decreases gradually as dye concentration increases from 1 to 4% owf. Due to the reduction of the number of available reacting sites in the fabric at high dye concentration, in addition to the probability of occurring dye aggregation by increasing the dye concentration, which in turn reduces the dye substantivity towards the fabric.

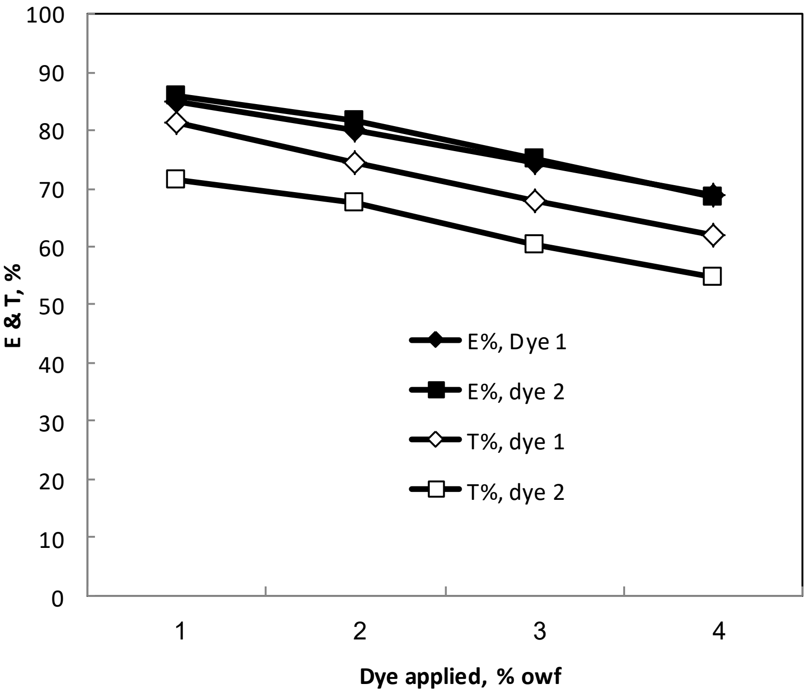

Figure 6: E% and T% of polyfunctional reactive dye 1 compared with that of the commercial reactive dye 2 at different concentrations on cotton fabric.

3.3. Measurements

3.3.1. UV protective properties of the dyed fabrics

The UPF values of the samples dyed with both dyes **1** and **2** are given in Table 1. The results indicated that, the UPF values of the samples dyed with the polyfunctional reactive dye **1** exceed by about 19-22% than those dyed with the commercial reactive dye **2**, over the range of dye concentration. We can also notice from Table 1 that the UPF values of the dyed samples for both dyes increase as the dye concentration increases. This emphasizes the meaning that as the fabric dye content increases the UV protective properties of the dyed fabrics in turn increase.

In other meaning, we can notice that the UPF value of the sample dyed with the polyfunctional dye 1 using 4% owf concentration exceed by about 19% than the UPF value of the equivalent sample dyed using the commercial dye 2, while, the total fixation of this sample dyed using the polyfunctional dye 1 (as detected from Figure 6) exceed by 11% than that of the commercial dye 2. This emphasis the meaning that the two additional reactive groups presented in the polyfunctional has efficiency for enhancing UV protective properties higher than its efficiency in enhancing the total fixation properties. This indicated that the type of reactive group added (SES), may itself have UV absorbing properties.

Samples	Shade, %owf	UPF	UV-A	UV-B
Control	-------	1.7	53.7	57.8
Dye **1**	1	27.2	4.8	3.7
	2	34.1	3.6	2.9
	3	41	2.7	2.4
	4	48.6	2.0	1.9
Dye **2**	1	21.4	6.5	4.6
	2	27.4	4.9	3.6
	3	33.4	3.7	3.1
	4	39.2	3.1	2.6

Table 1: UV protective properties of cotton samples dyed with dyes 1 and 2.

3.2.2. Fastness properties

The fastness properties of the polyfunctional reactive dye 1 and the commercial reactive dye 2 were tested on cotton fabric using 2 and 4% owf dye concentrations at the specified optimum conditions for each dye. The results are given in Table 2. The results clearly show that the perspiration and washing fastness properties of the samples dyed using the polyfunctional reactive dye 1 were higher than those of the samples dyed with the commercial reactive dye 2. While both dyes secured the same results for the light and rubbing fastness.

Dyes	**Dye Conc. % owf**	**Fastness to rubbing**		**Washfastness**			**Fastness to perspiration**						**Light**
							Alkaline			**Acidic**			
		Dry	**Wet**	**Alt**	**SC**	**SW**	**Alt**	**SC**	**SW**	**Alt**	**SC**	**SW**	
Dye 1	2	3-4	3-4	5	4	5	5	4	5	5	4-5	4-5	5
	4	3-4	3-4	5	3-4	4	5	4	5	5	4-5	4-5	
Dye 2	2	3-4	3-4	5	3-4	4	5	3-4	4-5	5	3-4	4	5
	4	3-4	3-4	5	3	3-4	5	3	4-5	5	3	3-4	

Table 2: Fastness properties of cotton fabric dyed with reactive dyes 1 and 2.
Alt, alteration. SC, staining on cotton. SW, staining on wool.

4. Conclusion

Synthesis and characterization of polyfunctional reactive dye **1** modified from a commercial reactive dye **2** (CI Reactive Red 120) were obtained by replacing the two orthanilic acid moieties presented in the commercial reactive dye by two 1-aminobenzene-4-β-sulphatoethylsulphone moieties. The optimum conditions of both dyes were determined using the exhaust dyeing method.

The polyfunctional reactive dye **1** not only enhancing the dyeing properties of cotton fabric but also enhancing the UV-protective properties of cotton fabric compared to the commercial dye **2**. Also the polyfunctional dye **1** has efficiency for enhancing UV protective properties higher than its efficiency in enhancing the total fixation properties. This indicated that the type of reactive group added (SES), may itself have UV absorbing properties.

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