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A Novel Green Continuous Dyeing of Polyester Fabric with Excellent Color Data

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POLYESTER fabrics are conventionally dyed mainly at either high temperature and high pressure or normal pressure using a toxic carrier. These harsh method not only energy consuming but as well affects the environment severely. Thus, for cleaner production and with an eye on energy saving, a green and ecological viable and sustainable continuous dyeing process were developed for polyester fabrics using aqueous polyethylene glycol (PEG). Polyester fabrics were dyed with CI Disperse Blue 56 in a continuous process by padding the fabric in an aqueous solution of PEG10000 with 100% pick-up. Different factors that may affect the dyeability of polyester fabrics, such as PEG water ratio, drying time and method, curing temperature and time, were investigated. The selected conditions obtained were applied using four disperse dyes; namely, CI Disperse Blue 56, CI Disperse Red 50, CI Disperse Red 343, and CI Disperse Orange 29. A tentative mechanism is suggested for the role of PEG10000 in the dyeability of polyester fabrics that relies on nanodispersed dye together its action as a fiber plasticizer and swelling agent. The excellent color data, levelling and fastness properties of the dyed fabrics using this facile method suggest its potential as a viable and ecological alternative for carrier-atmospheric dyeing and high-temperature dyeing of polyester fabrics with great potential for application to a broad range of synthetic fibers.

Keywords: Ecological, Green dyeing, Nanodisperse dye, Polyester, Continuous dyeing, Polyethylene glycol

Introduction

Poly(ethylene terephthalate) (PET) is the most growing and widely used fiber in the textile industries, owing to its excellent physical and chemical properties [1,2]. However, PET fibers are a hydrophobic, compact, and crystalline polymer that lacks chemically reactive groups, a characteristic that hampers its coloration [3,4]. Conventional dyeing of PET fabrics with disperse dyes proceeds in a high-pressure vessel at high temperature (130°C) with potential risk and high-energy consumption [5]. The other choice is to use a toxic carrier for good dyeability at atmospheric pressure [6,7]. Both industrial methods are damaging the environment owing to the use of toxic textile auxiliaries. In addition, these methods consume a huge amount of water that is ultimately discharged to the environment, causing pollution with the remained auxiliary chemicals and unexhausted disperse dyes [8].

Attempts have been reported to overcome these circumstances. These are chemical modification of PET fibers, replacement of textile auxiliaries with less or nontoxic ones, or using new technologies based on physicochemical changes in textile fabrics [9–11]. Water-free dyeing either using supercritical carbon dioxide dyeing or solvent-assisted dyeing of PET fabrics has been

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investigated. The limitations of using supercritical carbon dioxide dyeing method are the high cost of using highly pressurized equipment (up to 300 bar) and the dislocation of PET oligomers that ultimately affect the quality of the dyed product [12,13]. Solvent-assisted dyeing of PET fabrics, on the contrary, although replaces water and textile auxiliaries, yet it is a high-temperature method, that is, energy consuming, and lacks green solvents for all colors [14]. Application of nanotechnology using nanoemulsion was also persuaded for a partial saving of water with better dyeability, although with concerns in using emulsifier and other water-soluble auxiliaries as well as dyeing at high temperature and pressure [15,16]. A green approach of PET dyeing at atmospheric pressure was attained after its irradiation with a germicidal lamp while being chemically modified using aqueous H_2O_2 and H_2O_2 in the presence of acrylic acid solutions at room temperature under air [9].

The substitution of toxic carriers in atmospheric dyeing of PET fabrics using vanillin and vanilla to facilitate dye adsorption and diffusion into the fabrics has been studied. Vanillin and vanilla are an agro-natural source; however, their potential as carriers in PET dyeing are limited with small disperse dye molecules together with the need to use a large amount of these carriers [17–19]. Recent studies on dyeing of PET fabrics have also been reported using eutectic solvent based on a mixture of choline chloride, urea, and glycerin in the proportion of 1 : 1 : 1 (w/w) as a substitute of toxic carrier [20].

Thermosol process for continuous dyeing of PET fabrics is also one of the three conventional methods. It is a continuous process started by padding the PET fabric in the dye-bath, although containing nonecofriendly textile auxiliaries, squeezed, dried (about 120°C), and cured for dye fixation at about 220°C. The thermosol process is applicable for limited color shades, as it is designed only for sublimable disperse dyes at such high temperature so that dyes can diffuse in the gaseous phase within PET fibers [21,22].

In the interest of continuous dyeing as it is carrier-free with excellent dye utilization and aiming at finding a novel ecological dyeing method of PET fabrics, it was hypothesized that using polyethylene glycol (PEG) aqueous solution without any textile auxiliaries in the presence of disperse dye in a dye-bath for padding PET fabrics would be facile, viable, and a green process. PEG is on the list of FDA's GRAS as a green medium. It is chemically stable, its liquid form (low molecular weight) is miscible with water, and its solid form (high molecular weight) is highly soluble in water at room temperature [23].

In the present work, PEG10000 was selected, as it is solid at room temperature (m.p. about 65°C), and thus after padding the fabric in aqueous PEG10000 containing disperse dye, the absorbed dye would remain inside the fabric with homogeneity. Additionally, PEG10000 or higher molecular weights are reported as the best plasticizers for polymeric fibers [24]. To the best of our knowledge, the present work is novel, and the results obtained would inspire scientists for further investigation and possible industrial application.

Experimental design

Materials

Scoured and bleached 100% polyester fabric (149 g/m^2) was supplied by El-Mahalla El-Kobra Company, Egypt. The fabrics were further scoured in aqueous solution with a liquor ratio of 1 : 50 containing 2 g/l nonionic detergent solution (Hostapal; Clariant, Egypt) and 2 g/l Na_2CO_3 at 50°C for 30 min, then rinsed thoroughly, and dried. The commercial dyes used in this study were used as received. These dyes (Fig. 1) are Dianix Red CC (CI Disperse Red 343), Foron Scarlet E-2GFL (CI Disperse Red 50), Dianix Classic orange SE-R (CI Disperse Orange 29), and Foron Blue E-BL (CI Disperse Blue 56). Dianix and Foron disperse dyes were kindly supplied from Dystar and Sandoz, respectively. Hosptabal CV (Clariant, Egypt) was used as a nonionic soaping agent. All other chemical reagents were of laboratory grade.

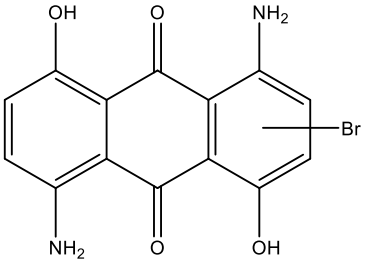
Green dyeing of poly(ethylene terephthalate) fabric

Preparation of the padding dye-bath

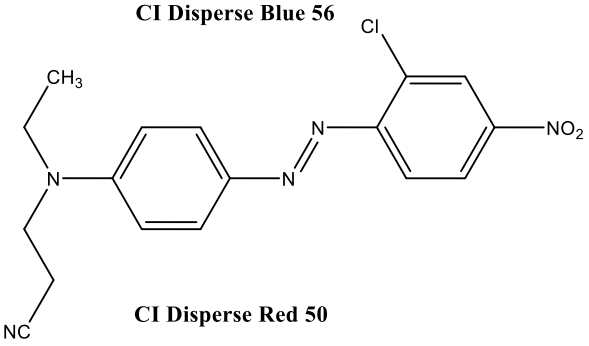
PEG10000 solution was made by dissolving 5–15 g in 18 ml water at 60°C for 15 min. Dye (0.5 g) was dispersed in water (2 ml) at 60°C for 15 min. Then both components were mixed and homogenized at 60°C for 15 min.

Pad-dry-curing method

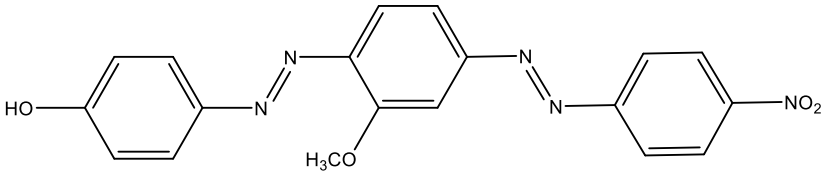
Dyeing of PET fabrics with disperse dyes was carried out using a '2-dip-2-nip' padding at room temperature in a dye-bath made as mentioned before. The padded fabrics were then dried and cured. Details of the conditions used are given in the text. Finally, the dyed fabrics were rinsed with water and washed in liquor ratio of 1 : 50 with



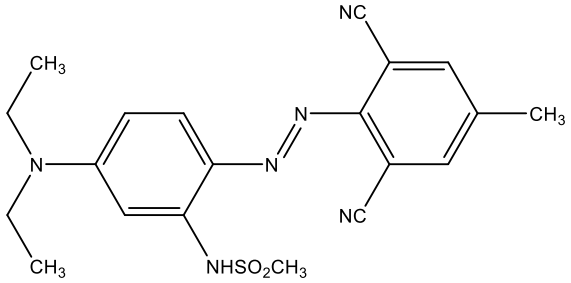
CI Disperse Blue 56



CI Disperse Red 50



CI Disperse Orange 29



CI Disperse Red 343

Fig. 1. Disperse dyes used.

nonionic detergent (Hostapal CV), 2 g/l at 60°C for 30 min. The fabrics were then thoroughly rinsed with water and dried.

Color measurements and levelling

The colorimetric properties of dyed PET fabrics were obtained using a Hunter Lab Ultra Scan PRO (Reston, Virginia, USA) in terms of CIELab and CIELch values (L*, a*, b*, c*, h°) using a standard illuminant D65 and 10° observer with specular radiation excluded on a Minolta CM-3600d visible spectrophotometer and provided with Spectramagic software [25,26] (Fig. 2). According to this system, three basic tristimulus components of color, namely, hue (h°), chroma (C*) (also referred to as saturation), and Lightness (L*) (also referred to as luminance), were measured. The hue angle was measured from 0 to 360°. The values of the two coordinates a* and b* were also determined. L* represents the lightness or darkness of a color (L*=100 for white and L*=0 for black) whereas a*=red to green (+a*=redder, −a*=greener), and b*=yellow to blue (+b*=yellower, −b*=bluer), and where the two 'color' axes intersect=neutral gray.

The chroma (c*) and hue angle (h°) were measured by using following equations:

$$\text{Chroma } c^* = \sqrt{a^{*2} + b^{*2}} \quad (1)$$

$$\text{Hue angle } h^{\circ} = \tan^{-1}\left(\frac{b^*}{a^*}\right) \quad (2)$$

The color strength, expressed as K/S values of the dyed samples, was measured by using a Hunter Lab Ultra Scan PRO at the maximum wavelength of the dye used. The relative color strength (K/S values) was assessed using the Kubelka–Munk equation (1) [27]:

$$\frac{K}{S} = \sqrt{\frac{(1-R)^2}{2R}} \quad (3)$$

where R is the reflectance of colored samples and K and S are the absorption and scattering coefficients, respectively.

Moreover, the leveling properties of dyed samples were assessed by measuring the color differences within the same sample at five different points, and the average value between these points was determined. This average color difference was used as an indication of the leveling [4,28–30].

Thermal analysis and transmission electron microscopy

Thermogravimetric analysis (TGA) was carried out on a Shimadzu TGA-50H thermogravimetric analyzer (Columbia, USA), and the samples were heated from room temperature to 700°C at a rate of 10°C/min under an inert nitrogen atmosphere. Transmission electron microscopy (TEM, Model; JEOL-1230, Tokyo Japan) was used to observe the dispersed nanoparticles.

Fastness testing

The dyed samples were tested, after washing-off using 2 g/l nonionic detergent (Hostapal CV) at 60°C for 30 min, according to ISO standard methods [31]. The specific tests were ISO 105-C02 (1989), color fastness to washing; ISO 105-E04 (1989), color fastness to perspiration; and ISO 105-X12(1987), color fastness to rubbing.

Results and Discussion

It was envisioned that finding a green formulation for continuous dyeing of PET fabrics would be of great interest. Recent studies have

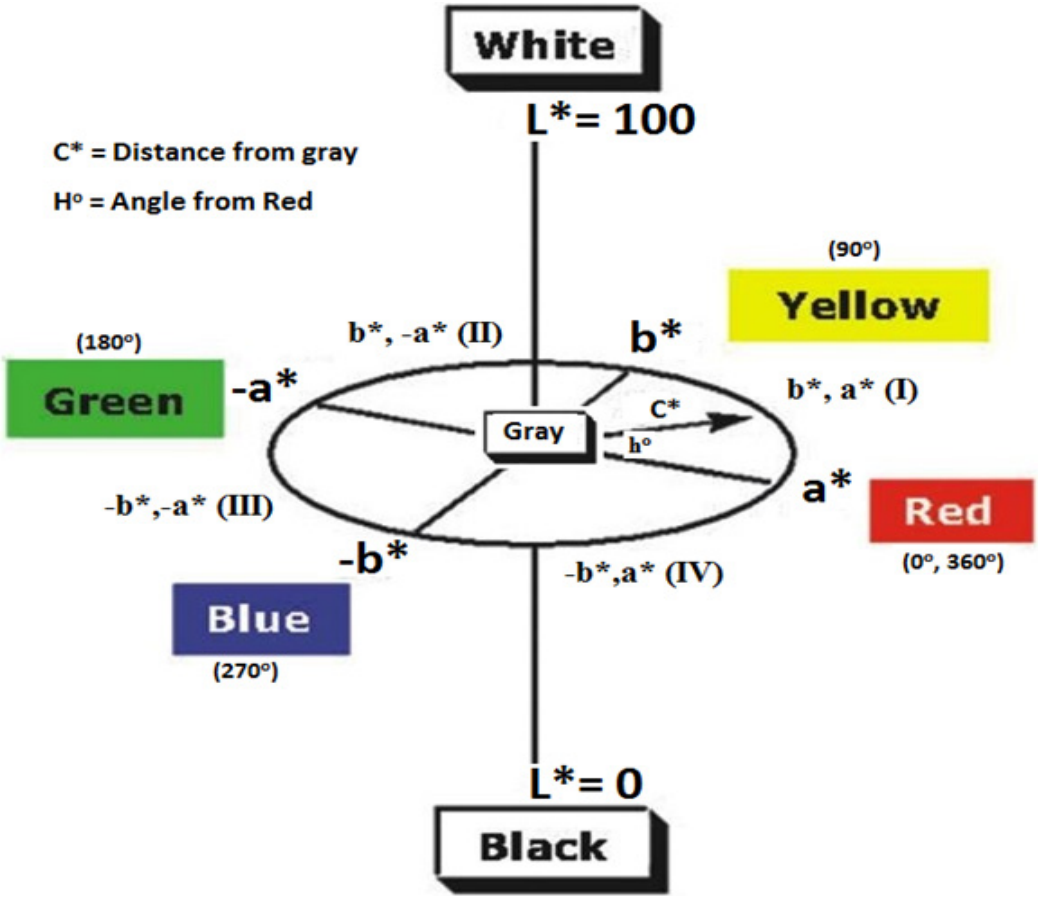


Fig. 2. CIELAB color space.

indicated that PEG, in general, is an effective external plasticizer for different polymers [24,32]. Therefore, PEG10000 as a green medium [23] was selected, as it would play two roles, one as a good dispersing and solubilizing agent for the disperse dye and the other as an external plasticizer and swelling agent for PET fabrics, and thus it facilitates dye diffusion and results in a good dyeability of PET fabrics. In this interest, the different factors that may affect this process are investigated.

Effect of curing temperature

The effect of curing temperature on the dyeability of PET fabrics with CI Disperse Blue 56 was conducted at different temperatures (130, 150, 170, 190, and 210°C), and the conditions are indicated in the legend of the figure. As shown in Fig. 3, the color strength of dyed fabrics increases as the curing temperature increased up to 170°C, after which, it decreased with further increases in the temperature. This result reflects the suitable temperature of dye dissolution inside PET fabrics with good dyeability. Upon increasing the temperature beyond 170°C, the disperse dye retention in PEG and/or its decomposition may badly affect its fixation.

Effect of curing time

The effect of curing time on the dyeability of PET fabrics with CI Disperse Blue 56 was conducted at different times (30, 50, 90, and 150 s). As shown in Fig. 4, the color strength of dyed fabrics increases as the curing time increased up to 90 s, after which it decreased with further increases in the time. This result indicates that 90 s was enough for good dyeability, and prolonging the time may lead to reversal of the fixation to PEG and/or the decomposition of the dye.

Effect of drying time

The effect of drying time on the dyeability of PET fabrics with CI Disperse Blue 56 was conducted at different times (1, 3, 5, and 7 min). As shown in Fig. 5, the color strength of dyed fabrics increases as the drying time increased up to 5 min after which it decreased with further increases in the time. This result indicates that 5 min was enough for drying the fabric of the absorbed water, leading to further dye diffusion, and prolonging the time may reverse the diffusion back to PEG (Fig. 5).

Effect of polyethylene glycol water ratio

The effect of PEG water ratio on the dyeability of PET fabrics with CI Disperse Blue 56 was conducted at different ratios (0 : 20, 5 : 15, 10 : 10, and 15 : 5 w/w PEG/water). As shown in Fig. 6, the color strength of dyed fabrics was the best at the ratio of 5 : 15, after which the dyeability decreased. This result indicates that 5 : 15 PEG/water ratio is suitable for dye fixation, above

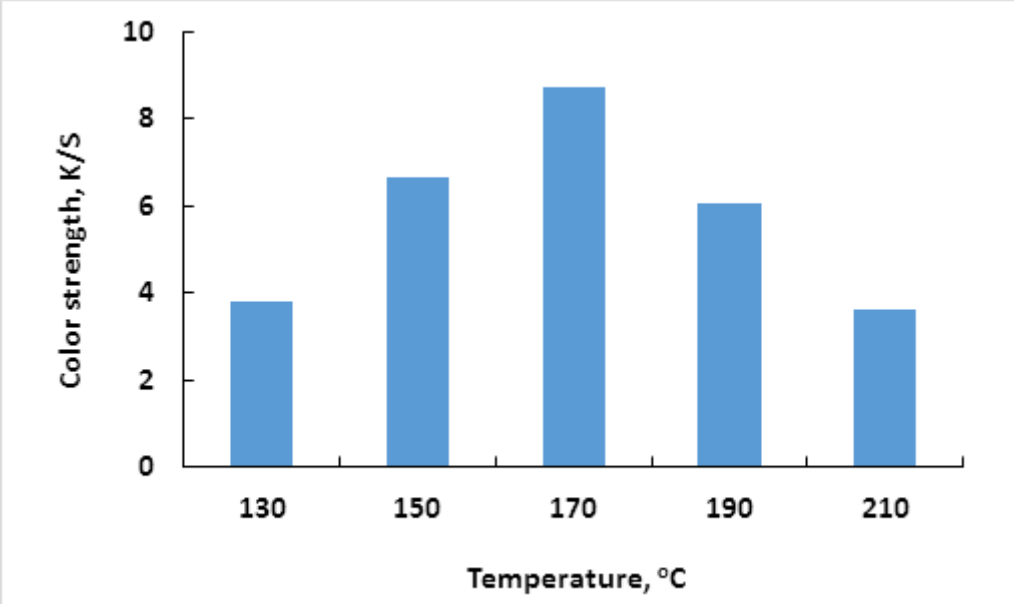


Fig. 3. Effect of curing temperature on the color strength of the dyed PET fabrics.
Dyeing conditions: Padding (2-dip-2-nip) in a dye-bath containing PEG10000 (15 g), H_2O (20 ml), dye (0.5 g), drying at 80 °C for 5, curing curing for 1 min.

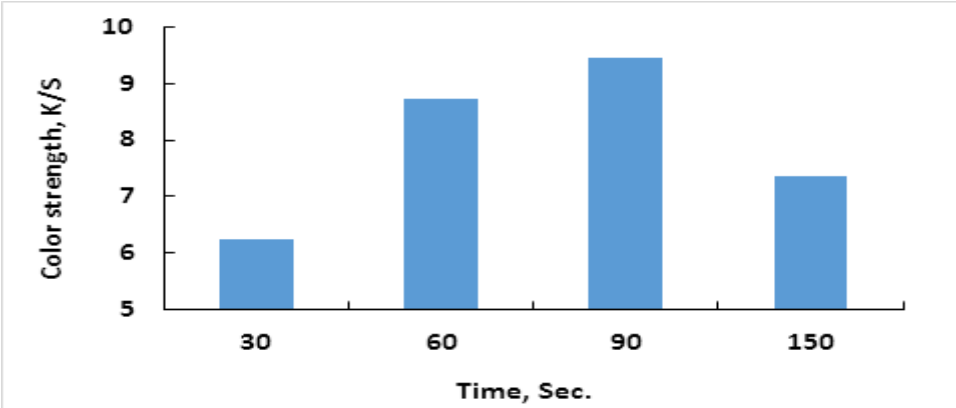


Fig . 4. Effect of curing time on the color strength of the dyed PET fabrics.
Dyeing conditions: Padding (2-dip-2-nip) in a dye-bath containing PEG10000 (15 g), H_2O (20 ml), dye (0.5 g), drying at 80 °C for 5, curing at 170 °C.

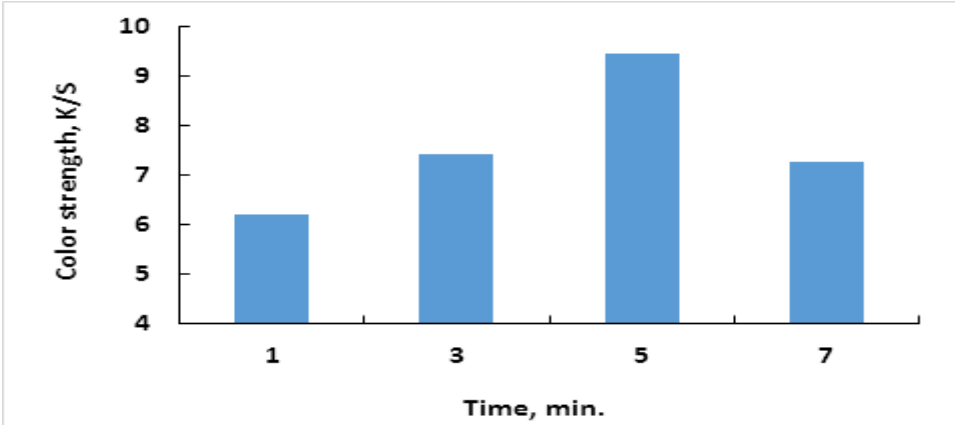


Fig. 5. Effect of drying time on the color strength of the dyed PET fabrics.
Dyeing conditions: Padding (2-dip-2-nip) in a dye-bath containing PEG10000 (15 g), H_2O (20 ml), dye (0.5 g), drying at 80 °C, curing at 170 °C for 90 sec.

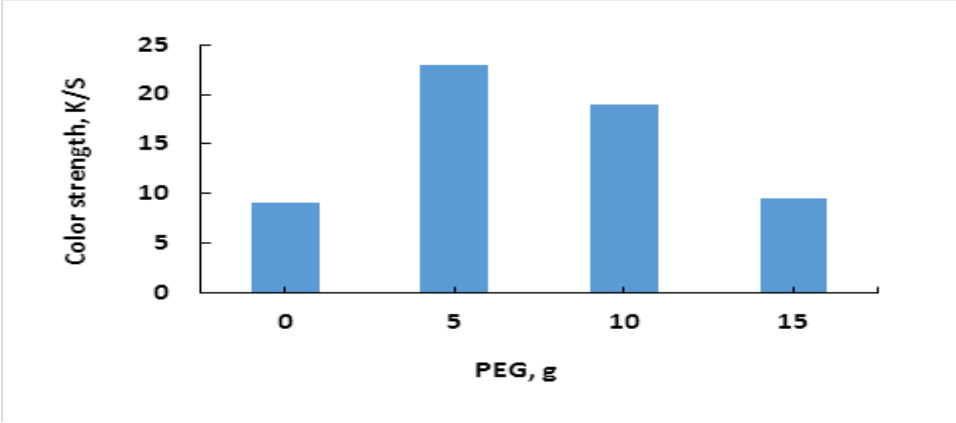


Fig. 6. Effect of PEG/water ration on the color strength of the dyed PET fabrics.
Dyeing conditions: Padding (2-dip-2-nip) in a dye-bath containing PEG10000 (5-15 g), H_2O (20 ml), dye (0.5 g), drying at 80 °C for 5, curing at 170 °C for 90 sec.

which the retention of disperse dye will certainly dominate PEG medium, leading to a lower dyeability of PET fabrics.

Comparative drying

It was interesting to see whether drying at room temperature of the padded fabric would bring a similar dyeability with that dried at 80°C. Thus, two comparative experiments were done, and the results obtained are shown in Fig. 7. Expectedly, the color strength of the dyed fabrics obtained after drying at 80°C for 5 min was equivalent to that obtained after drying at room temperature for 15 min. This result indicates that the role of drying is to eliminate absorbed water from the fabrics, which is why long drying time at 80°C, as observed above, was not suitable owing to the possibility of dye migration from the fabric to PEG.

Comparative color strength of environmentally friendly dyeing methods

Table 1 shows a comparative color strength of reported environmentally friendly dyeing methods using CI Disperse Blue 56 with the present work, which demonstrate that the current method is a facile and novel continuous method with excellent color strength of the dyed fabrics.

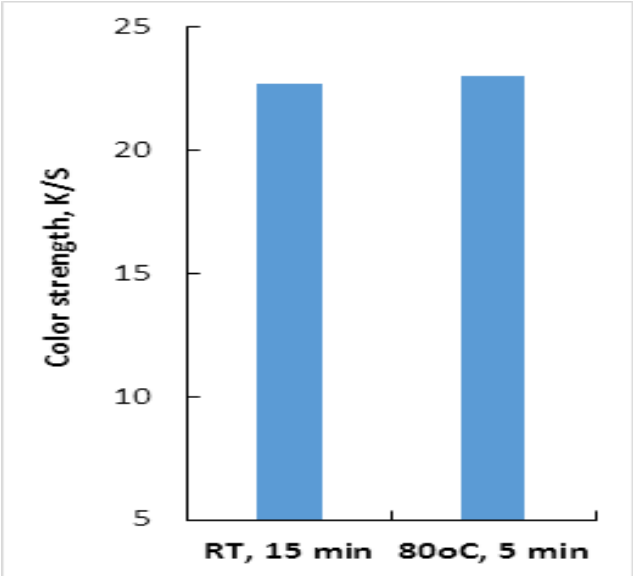


Fig. 7. Comparative color strength of the dyed PET using different drying methods. Dyeing conditions: Padding (2-dip-2-nip) in a dye-bath containing PEG10000 (5 g), H_2O (20 ml), dye (0.5 g), drying at 80 °C for 5 min or at room temperature for 15 min, curing at 170 °C for 90 sec.

TABLE 1. Comparative color strength of dyed PET fabrics using CI Disperse Blue 56 under different environmentally friendly conditions.

Dyeing method	K/S	Ref.
Solvent (Liquid paraffin) High-temperature	18.72	13
Vanilla (carrier) Atmospheric	24.14	17
Solvent (eutectic) High-temperature	10.45	18
Pad-dry-curing	23.22	This work

Tentative mechanism

The role of PEG during the dyeing process might be indicated by studying the effect of PEG on both PET fabrics and the particle size of the dye molecule during the dyeing process. For this purpose, CI Disperse Blue 56 was selected as a representative disperse dye, and PET fabrics were simply dyed in the presence and absence of PEG. Moreover, PET fabric sample as the control was processed following the same dyeing procedure in the presence of aqueous PEG except in the absence of dye. These three samples, together with pristine PET fabric sample, were thermally analyzed under nitrogen. Furthermore, the effect of PEG aqueous solution on the particle size of dispersed dye was assessed in comparison with the particle size of water dispersed dye.

Thermogravimetric analysis

Figure 8 and Table 2 show the TGA results under the nitrogen atmosphere generated on different PET fabrics. All samples undergo thermal degradation, mainly in two stages. Stage 1 from 400 to 480°C shows the most weight loss of the samples (69–77%) because of the depolymerization of PET fabrics. Stage 2 from 480 to 600°C shows the lower weight loss of the samples (about 4%) owing to the completion of oxidative degradation of the ash content in the residues. There was no weight loss beyond 600°C, and the char residue was in the range of 20–28%. Similar thermal behavior of PET fabric was reported [33–35]. The difference between the TGA of pristine PET fabric (PET), PEG treated (PET-PEG), pristine dyed (PET-dye), and PEG-treated dyed one (PET-PEG-dye) can be observed clearly. As shown in Fig. 8 and Table 2, it is clear that PET-PEG sample is thermally more stable than the PET sample. This result indicates the favorable effect of PEG on reorganizing the polymeric chains such that hydrogen bonds take place between the chains. These results are in accordance with those previously reported, in which using PEG as plasticizer and swelling agent could lead to an increase in the thermal stability of polymeric fibers, as it facilitates the formation of soft and flexible polymer [24].

Interestingly, the thermal stability of PET-PEG-dye sample was lower at 50% degradation than the thermal stability of PET-dye sample, and both samples were lower than the pristine PET and PET-PEG samples. On the contrary, the residue remained at 600°C for PET-PEG-dye sample was higher than that of PET-dye sample. These results reflect two factors: one, the effect of dye molecules inside the polymeric fabrics, and the second, the effect of PEG on the dye uptake. The presence of dye molecules inside the polymeric chains may break the physical bonds between the chains and thus affects its thermal stability. Dyeing of PET fabric in the presence of PEG increased its dye uptake as reflected by the higher residue for PET-PEG-dye sample compared with PET-dye sample.

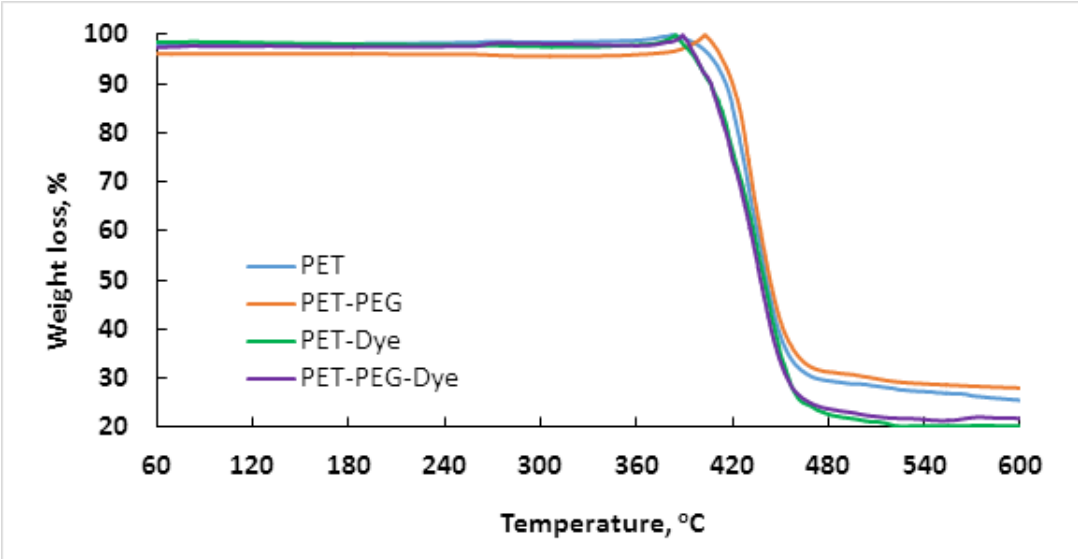


Fig. 8. TGA of PET, PET-PEG, PET-Dye and PET-PEG-Dye fabric samples.

TABLE 2. Thermogravimetric data of pristine polyester (PET), PEG treated (PET-PEG), pristine PET dyed (PET-Dye) and PEG treated and dyed (PET-PEG-Dye) fabric samples.

Samples	Temperature, °C (50% weight loss)	Residue at 600 °C, %
PET	441	26
PET-PEG	444	28
PET-Dye	440	20
PET-PEG-Dye	437	22

Transmission electron microscopy analysis

TEM images for the dispersed dye (CT Disperse Blue 56) in the presence and absence of PEG aqueous solution are shown in Fig. 9. Dark particles of size range from 6 to 30 nm for the dye are surrounded by the bright entities of PEG, whereas for the water dispersed dye, the image shows aggregates of dye particles of size range of 46–76 nm. This result indicates that PEG decreased the particles of dispersed dye. Based on TGA and TEM data, it has become clear that PEG plays two crucial roles in the dyeability of PET, as a fiber plasticizer and a suitable dispersant for the dye. The decreased particle size of dispersed dye owing to PEG aqueous solution increased its surface area leading to higher adsorption of the dye onto the fabric surface. On the contrary, the plasticization of PET fabric imparted by PEG would facilitate dye absorption and thus higher dyeability.

Application on different dyes

The selected dyeing conditions based on the aforementioned studies were implemented on four different disperse dyes, namely, CI Disperse Red 343, CI Disperse Red 50, CI Disperse Orange 29, and CI Disperse Blue 56 (Fig. 1). The dyeability of PET fabrics using these dyes was evaluated in the presence and absence of PEG and with or without fixation (curing). Figure 10 shows how the method presented was successful for all dyes and depending on their chemical structures. Images of the dyed samples in the presence and absence of PEG are shown in Fig. 11. The overall results indicate that the fixation in the presence of PEG resulted in an excellent dyeability.

The color data in terms of CIELab and CIELch values (L*, a*, b*, c*, h°) were measured, and the results shown in Table 3 indicate that PET fabrics dyed in the presence of PEG have the highest L* compared with no PEG, indicating a brilliant shade. The chroma (c*) and hue (h°) were more or less the same for all samples, indicating the use of PEG did not change the color of the dye used.

The chemical structure of the dyes used may affect the color strength obtained, as shown in Fig. 10. The color strength obtained was in the following order: CI Disperse Blue 56>CI Disperse Red 343 CI Disperse Reda 50>CI Disperse Orange 29. This order may be attributed to the size of the dye as well as its solubility tendency in PEG. CI Disperse Orange 29 is a disazo dye with the largest molecular size, and the presence of hydroxyl group in the para position to the nitro group in the other side of the dye may lead to its polarizability and possible affinity toward PEG rather than PET fabrics.

The levelling properties of the PET fabrics dyed with the four dyes are shown in Fig. 12. The average color differences of the dyed fabrics using aqueous PEG solution were within the accepted range ($\Delta E<1$) of leveling, indicating good diffusion and penetration of disperse dyes within PET fabrics compared with those obtained in the absence of PEG.

Fastness properties

As shown in Table 4, the fastness tests of rubbing, washing, and perspiration of PET fabrics dyed with disperse dyes are generally better using PEG compared with those made in the absence of PEG. The improved fastness properties would be owing to the role of PEG, which results in a better dye penetration and thus good coverage with high fixation inside PET fabrics.

Conclusion

A novel and green continuous dyeing method of PET fabrics using aqueous PEG solution containing disperse dyes was explored as a viable and facile alternative for carrier-atmospheric dyeing and high-temperature dyeing of polyester fabrics. The excellent color data, leveling, and fastness properties obtained of dyed samples are suggested to be owing to the crucial role of PEG

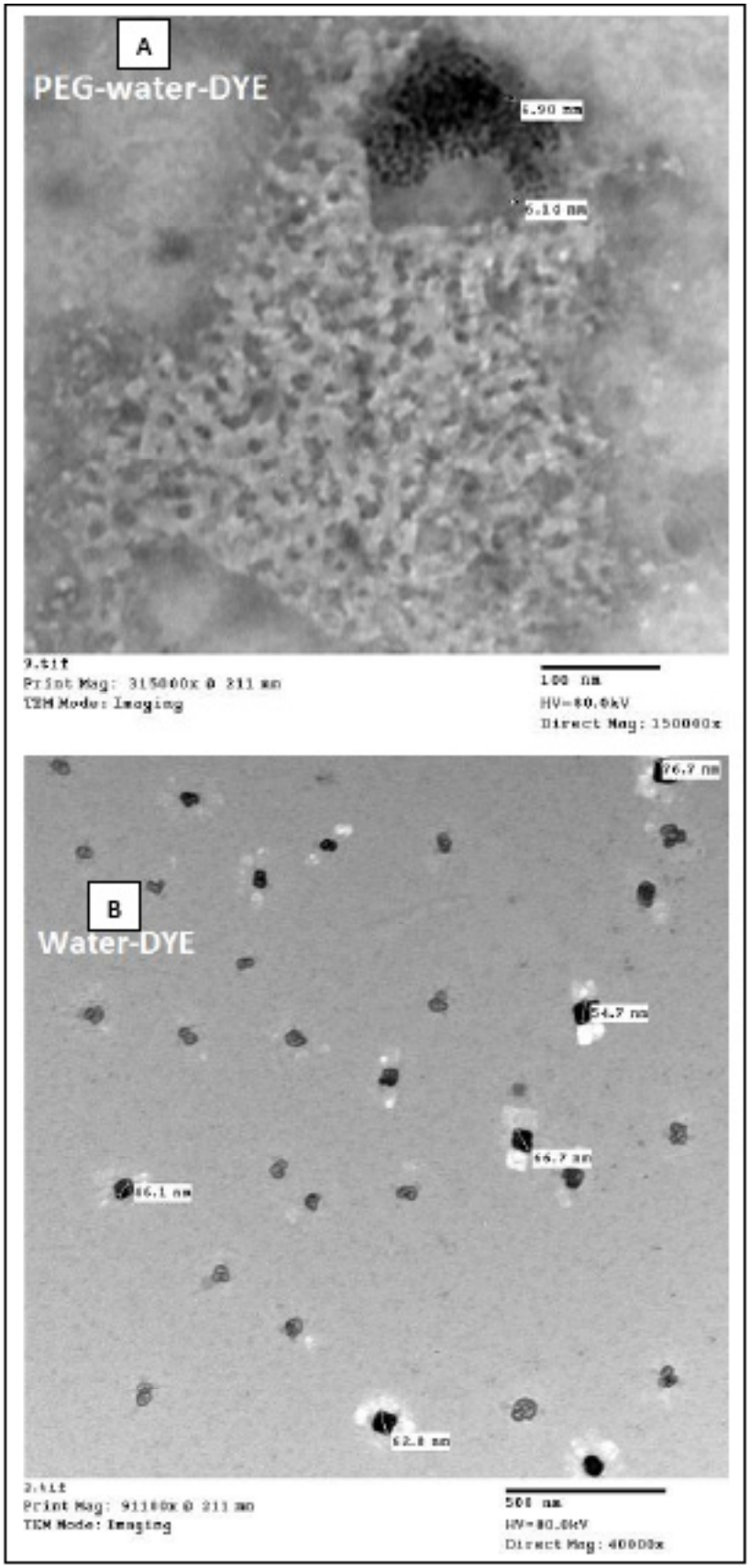


Fig. 9. TEM images of CI Disperse Blue 56 dispersed in aqueous PEG10000 (A) and water (B).

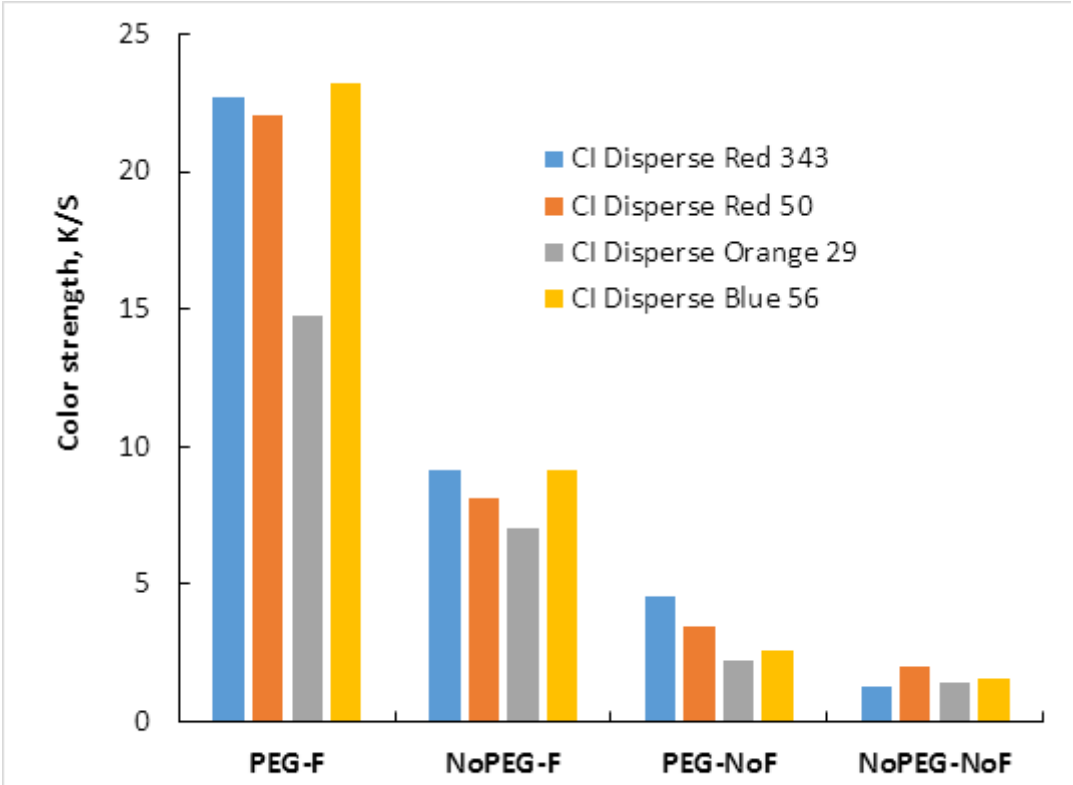


Fig. 10. Comparative color strength of the dyed PET fabrics in the presence and absence of PEG and with or without fixation. PEG-F=In the presence of PEG and after curing, NoPEG-F= In the absence of PEG and after curing, PEG-NoF= In the presence of PEG and without curing, NoPEG-NoF= In the absence of PEG and without curing.

Dyeing conditions: Padding (2-dip-2-nip) in a dye-bath containing PEG10000 (5 g) or without PEG, H_2O (20 ml), dye (0.5 g), drying at 80 °C for 5 min, curing at 170 °C for 90 sec or without curing.

Fig. 11. Images of the dyed PET samples with different dyestuffs in the presence and absence of PEG after being fixed following the conditions mentioned under Fig. 10.

TABLE 3. Application Color data of polyester fabrics dyed with different disperse dyes.
Dyeing conditions: Padding (2-dip-2-nip) in a dye-bath containing; PEG10000 (5 g), H_2O (20 ml), dye (0.5 g), drying at 80 °C for 5 min or air dying for 15 min, curing at 170 °C for 90 sec.

Dyes	L*		a*		b*		c*		h°		λ_{max}, nm	K/S	
	PEG	No PEG	PEG	No PEG	PEG	No PEG	PEG	No PEG	PEG	No PEG		PEG	No PEG
CI Disperse Red 343	33.79	31.11	45.04	42.63	19.74	24.63	49.17	49.23	23.66	38.46	500	24.10	10.40
CI Disperse Red 50	30.05	29.75	46.17	43.42	23.08	21.57	51.61	48.48	26.56	26.41	480	20.09	11.78
CI Disperse Orange 29	46.46	41.30	35.21	33.41	38.83	40.94	52.41	52.84	47.79	50.78	440	18.43	10.32
CI Disperse Blue 56	30.02	26.63	8.05	6.31	-36.01	-32.60	36.89	33.20	282.60	280.90	630	23.22	9.14

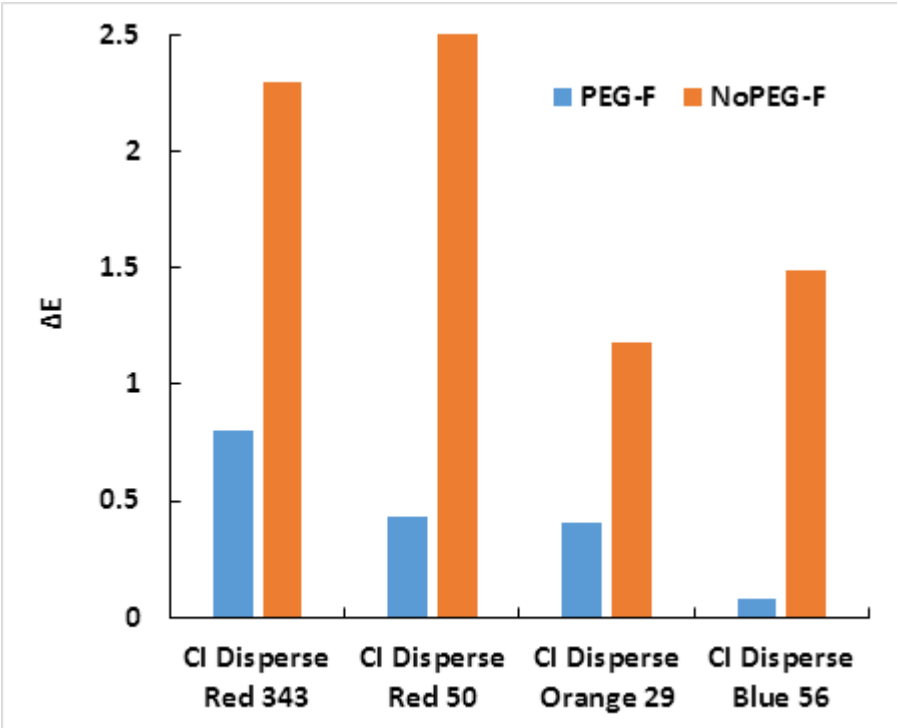


Fig. 12. Average of color differences (ΔE) of dyed PET fabrics using different disperse dyes in the presence of PEG after being fixed following the conditions mentioned under Fig. 10.

as a fiber plasticizer, swelling agent, and a suitable dispersant for the formation of nanodispersed dye. Future work on this subject is underway, and the outcome will be submitted for publication elsewhere. We believe that the method presented has a high potential for application to a broad range of synthetic fibers.

Conflicts of interest

The authors declared that there is no conflict of interest.

TABLE 4. Color fastness of dyed polyester fabrics using different disperse dyes in the presence and absence of PEG.

Dyes	Rubbing				Washing										Perspiration							
	Dry		Wet		A		SC		SP SC		SP		Acid A		SC		SP		Alkali			
	PEG	No PEG	PEG	No PEG	PEG	No PEG	PEG	No PEG	PEG	No PEG	PEG	No PEG	PEG	No PEG	PEG	No PEG	PEG	No PEG	PEG	No PEG	PEG	No PEG
CI Disperse Red 343	4	3-4	4	3-4	4-5	4	4	3-4	4-5	3-4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4
CI Disperse Red 50	4	3-4	4	3	4	3-4	4	3-4	4	3-4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4
CI Disperse Orange 29	4-5	3-4	4	3-4	4	3-4	4	3-4	4	3-4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4
CI Disperse Blue 56	4-5	3-4	4	3	4	3-4	4	3-4	4	3-4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4	4-5	4

Alternation (A), Staining on polyester fabric (SP), Staining on cotton fabric (SC).
Wash & Rubbing and perspiration: 1, poor; 2, fair; 3, good; 4, very good; 5, excellent.

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