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Original Research

Eco-Friendly Disperse Dyeing of Ultraviolet-Treated Polyester Fabric Using Disperse Yellow 211

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Abstract

A uniform and eco-friendly heating source, ultraviolet radiation has auspiciously improved the disperse dyeing of polyester fabrics. For our current study we used disperse yellow 211 (DY 211) to dye polyester fabric under the influence of ultraviolet treatment. Both the fabric and dye solution were UV-treated for 15-60 min and dyed under variable conditions. We found that ultraviolet-treated polyester (RP) for 30 min. gives good color strength and darker shades at 70ºC using 70 mL of un-irradiated dye solution (NRS) of pH 8 in the presence of 2% of dispersant. While for the dye bath of pH 11, irradiated polyester (RP) for 45 min. using 90 mL irradiated dye solution (RS) gives good color strength and darker shades at 100°C in the presence of 1% of dispersant. ISO standards for fastness revealed good-to-excellent ratings for different shades dyed under optimal conditions. Ultraviolet treatment not only reduced the time, labor, and money, but also improved color characteristics.

Keywords: disperse yellow 211, colorfastness properties, polyester fabric, Spectraflash SF600, ultraviolet irradiation

Introduction

Dyes are widely used in the cosmetics, textile, leather, food, paper and plastic industries, but in view of toxicity, these dyes show carcinogenicity towards the environment in the form of effluents [1], due to which the dye bath needs modifications that not only reduce the effluent load but also make the textile processing ecofriendly. Modifications involve the use of modern techniques [2] such as ultraviolet radiation [3], plasma [4], gamma [5-6] ultrasonic, and microwave [7] – all of which make the dyeing process cost-, time-, and labor-effective as well as sustainable. Of these techniques, the role of UV radiation is gaining popularity due to its treatment and efficiency. Previously it has been reported that UV radiation adds value in coloration, as well as improving fastness properties. Due to such wonderful benefits, these rays are used in textiles, wood, fibre, and

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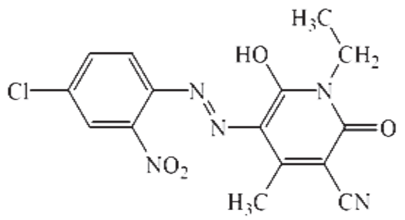
curing as well as in cosmetics. UV radiation processes have several advantages, including energy savings; low environmental impact; and simple, cheap, and high treatment speed [8]. Similarly, it has been determined that UV radiation can also be be used in dyeing textiles. UV surface modification occurred that is particularly useful on natural fibres such as wool and cotton synthetic colorants [9]. UV irradiation can improve color value in dyeing and printing via surface modification [10].

In the current study disperse yellow 211 (DY 211) was selected for dyeing polyester under the influence of UV radiation. DY 211 is a bright yellow dye with a pH range of 4 to 6 (structure given below). It is mostly used in the textile and paper industries. It shows excellent dispersion and compatibility with fabric that gives good color characteristics.



Disperse yellow 211 (C. I. No 12755)

The aim of current the study is to improve the dyeing behavior of polyester fabric using DY 211 under the influence of UV radiation.

Materials and Methods

DY 211 (C. I. No 12755) and polyester fabrics were procured from Sohaib Dyes and Chemicals in Faisalabad, Pakistan. Polyester fabrics and dye solution were exposed to UV irradiation (254 nm and 180 watt) for 15, 30, 45, and 60 min. at the Department of Chemistry of Government College University Faisalabad, Pakistan. All the chemicals used during the dyeing were of commercial grade. Dyeing of un-irradiated polyester fabric (NRP) and irradiated polyester fabrics (RP) were carried out at 90ºC for 35 min. keeping M:L 1:30.

Optimizing Different Dyeing Conditions

Dyeing of optimal fabrics was carried out for 10 to 60 min. using dye bath of pH 8 and 11. In order to achieve maximum dispersion of dye onto irradiated fabrics, 1-6% of Thymol N dispersant was employed at 60-100º C for 45 min. keeping M:L of 1:30 [11].

Evaluating Quality of Dyed Fabrics

CIE lab system using spectra flash (SF 600) equipped with an illuminant D 65 10º observer was used to investigate the effect of UV radiation by viewing K/S values at Eco-Friendly Color Chemistry Laboratory of the Department of Chemistry. Standard methods of ISO such as ISO105 CO3 for washing fastness, ISO105 X-12 for rubbing, and ISO105 BO2 for light fastness were applied, and ratings were made using grey scale to see the improvement in fastness characteristics before and after UV treatments.

Results and Discussion

The role of ultraviolet treatment in polyester dyeing is very promising because it makes the process ecofriendly as well as cost-, time-, and labor effective. The results given in Fig. 1a) for dyeing of polyester as pH 8 shows that UV irradiation of polyester for 30 min. gives high K/S using the un-irradiated solution (NRS). This is because irradiation for a short time does not cause any changes on the surface, while for higher exposure time the voids become too open to get diffusion of dye, due to which the dye bath equilibrium may face desorption resulting in low color depth. At optimal exposure time, the surface of polyester fabric is evenly tuned and maximum sorption occurs [11]. But when fabric irradiated for 45 min. is dyed under alkaline conditions (pH11) using an irradiated dye solution (RS, 45 min.), more K/S is obtained (Fig. 1b). This is because

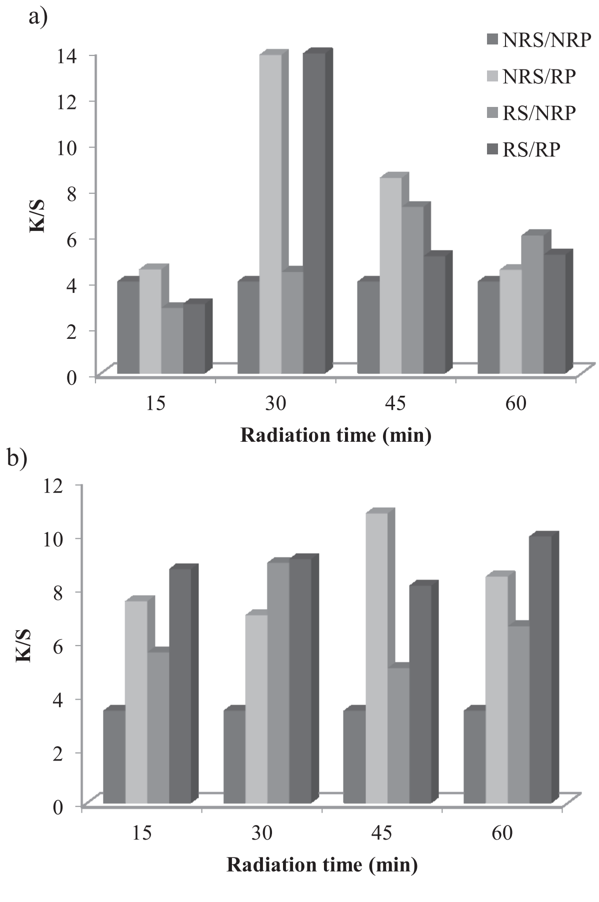


Fig. 1. Effect of ultraviolet treatment on dyeing of polyester fabrics at pH 8 a) and pH 11 b) using disperse yellow 211.

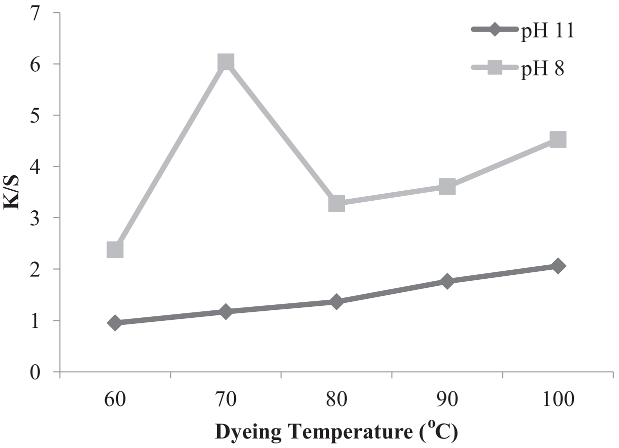


Fig. 2. Impact of dyeing temperature on k/s value of fabric dyed under optimal radiation conditions.

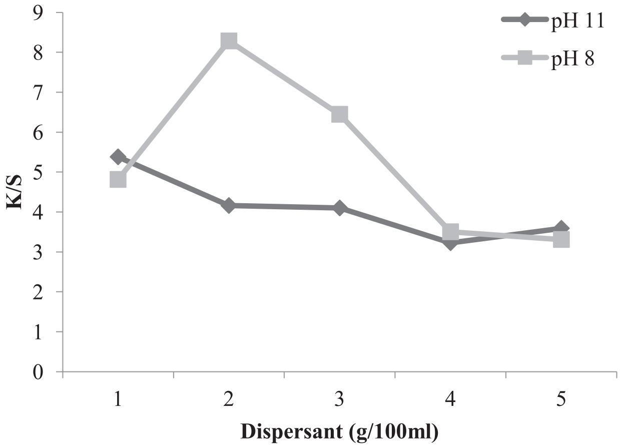


Fig. 4. Effect of dispersant on k/s of polyester fabric dyed under optimal radiation conditions.

under alkaline conditions some structural changes in the colorant might occur, which takes more time to diffuse into the fabrics (RP-45 min.) [12]. Hence it is recommended overall that a dye bath of pH 8 is more favorable for dyeing irradiated polyester fabric.

Mostly disperse dyeing is carried out at 110-140ºC, but ultraviolet treatment for both fabric and solution (RS/RP) at pH 8 and 11 has made it more convenient to dye at lower temperature. Fig. 2 shows that at pH 8 UV treatment of irradiated polyester (RP-30 min.) is favored at 70ºC using un-irradiated dye bath (NRS), while under alkaline (pH 11) conditions 100ºC is the optimal temperature for dyeing irradiated polyester using irradiated solution. This is because UV radiation adds value in coloration under mild conditions [13]. Hence depending upon the nature of the dye bath, the optimal temperatures are 70ºC and 100ºC.

Contact time is very important in disperse dyeing as it makes the equilibrium between dyeing bath and fabric after irradiation for 60 min. The results given in Fig. 3 show that UV radiation has reduced dyeing time. Because contact of fabric for a short time does not cause significant diffusion of dye into fibres, over longer periods desorption is favored due to stripping of color. Hence irradiation of polyester favors dyeing at 30 min. using un-irradiated solution (pH 8) and at 45 min. using irradiated solution (pH 11) [14].

Dispersant amount is necessary for dispersed dyeing because it imposes a negative charge on dye to improve its aqueous solubility and inhibits the formation of dye cluster through repulsion among negatively charged dye molecules. The more the dispersant amount, the more the even dyeing – but an over amount causes unevenness and aggregation in cluster on fabric surface to make the dyeing process dull [15-17]. The results given in Fig. 4 show that UV radiation has reduced the amount of dispersant. Hence 2% is an optimum amount for dyeing of irradiated polyester and un-irradiated dye solution (RP/NRS) in dye bath of pH 8, while for alkaline medium (pH 11), 1% is the optimum amount for maximum color strength.

The volume of dye bath also has a promising effect because ultraviolet treatment adds a significant contribution on disperse dyeing using DY 211.

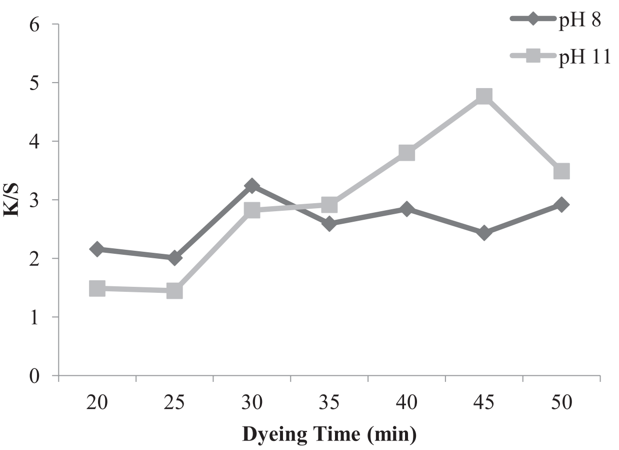


Fig. 3. Role of dyeing time on k/s value of polyester fabric dyed using optimal radiation conditions.

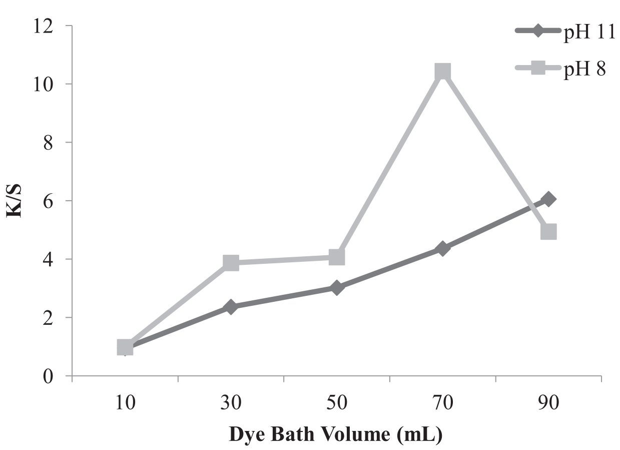


Fig. 5. Effect of dye bath volume on k/s value of polyester fabric dyed under optimal radiation conditions.

Table 1a. Effect of Ultraviolet radiation on colorfastness properties of polyester fabrics dyed at pH 8.

Shade	Light fastness	Wash fastness		Dry rub fastness	Wet rub fastness
		Color change	Color staining		
control	4/5	3/4	4/5	4	4
0.1	3/4	3/4	4	3/4	3/4
0.5	4/5	3	¾	4	4
1	3/4	3/4	4	3	3
2	4/5	3	4	3/4	3/4
3	4/5	3/4	¾	4	4
4	4/5	3/4	4	4/5	4/5

Table 1b. Effect of ultraviolet radiation on colorfastness properties of polyester fabrics dyed at pH 11.

Shade	Light fastness	Wash fastness		Dry rub fastness	Wet rub fastness
		Color change	Color staining		
Control	4/5	4	5	5	4/5
0.1	4/5	3/4	3/4	4/5	4/5
0.5	4	3/4	3/4	4/5	4
1	5	3/4	4/5	4	4/5
2	4/5	3/4	3/4	5	4/5
3	4/5	3/4	3/4	3	3/4
4	4	3/4	3/4	4/5	4

The results given in Fig. 5 show that UV treatment also shows a good trend by using 70 mL of dye bath (pH 8) given darker shades. This is because UV irradiation has physically modified the fabric (RP) surface in such a way that it sorbs the irradiated dye solution (RS) 70 mL more promisingly [18]. But the situation is reversed in the dye bath of pH 11, where 90 mL is optimal volume to get high K/S and acceptable fastness characteristics. Hence comparatively, pH 8 is more suitable for getting darker shades.

The rating results given in Table 1 (a-b) show that dyeing of polyester fabric with DY 211 using ultraviolet radiation has earned good ratings. Good light fastness is attributed to the presence of the benzenoid structure as well as conjugation system-aided auxochrome such as $-NO_2$, -CN, and -OH, which offers excellent resistance toward fading [19]. Similarly upon crocking, firm bonding between irradiated polyester and dye solution obtained by employing variable shade (0.1- 4) also shows the profound reinforcement toward detaching. Similarly, after tuning the fabric surface followed by dyeing at optimal conditions, the detergents also face high resistance to act upon the dyed fabric to stripe the color. Thus UV radiation of fabric using DY 211 gives a good fastness rating.

Conclusions

Ultraviolet irradiation treatment has improved the color strength values of the irradiated polyester fabrics by the application of disperse dyes. We observed that good color strength and fastness properties could be obtained. If irradiated polyester is dyed at 70ºC for 30 min. using media of pH 8 in the presence of 2% dispersant using 70 mL of un-irradiated disperse dye solution as compared to dyeing of irradiated polyester at 100ºC for 45 min. using 90 mL irradiated dye solution of pH 11 in the presence of 1% of dispersing agent using irradiated disperse dye solution, ultraviolet radiation can be successfully applied to enhance the color fastness properties as well as color strength without harming the chemical characteristics of polyester fabric.

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