

Disperse dyeing properties of (easy dyeable polyester)/spandex blend

M M Rahman¹, S M Mamun Kabir^{1,2}, H Kim¹ and J Koh¹

¹Konkuk University, Department of Organic and Nano System Engineering, 120 Neungdong-ro, Gwangjin-gu, Seoul 05029, South Korea

²Bangladesh University of Textiles, Department of Wet Processing Engineering Dhaka-1208, Bangladesh

Abstract. Using a low and a high energy disperse dye, several dyeing properties, like colour depth, partition ratio, degree of dye exhaustion, build-up and fastness properties of (easy dyeable polyester)/spandex blend were thoroughly investigated. Various dyeing temperatures ranging from 90 °C to 130 °C were applied. To check its performance, the conventional (regular polyester/spandex) blend was also dyed. (easy dyeable polyester)/spandex blend showed higher dyeability on PET and lower staining on spandex at low temperature compared to (regular polyester)/spandex blend..

1. Introduction

Spandex (generic name of polyurethane fiber) has the unusual characteristics of high elasticity. In textile industry, it is usually blended with other fibers. Although the blend ratio is very low, it imparts the blend excellent comfortability and wear ability [1].

The textile technologists usually encounter two major problems during disperse dyeing of (regular polyester)/spandex blend, namely (i) dye ability at low temperature in order to protect the spandex from damage and (ii) lower degree of wet fastness properties of the blend due to staining of spandex, [2]. To solve those difficulties, the researches were focused on identifying dyes that would exhaust less on the spandex and would have excellent dyeing behavior on the (regular polyester)/spandex blend at lower temperature [2-4]. As the spandex being more accessible to the alkaline reduction chemicals than the polyester, some researchers also examined the efficiency of reduction cleaning process on the removal of the disperse dye stain from the spandex [5].

In this present study, to overcome those two technical problems, a chemical modification of regular polyester named as easy dyeable polyester (abbreviated as EDP, Figure 1) through copolymerization had been adopted without changing the bulk properties of the regular polyester. Disperse dyeing properties of spandex and easy dye able polyester, and regular polyester fibers were studied.

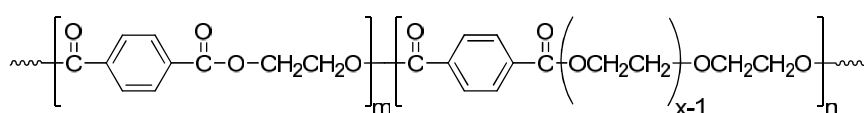


Figure 1. Chemical Structure of EDP

2. Experimental

2.1. Material

Spandex knitted fabric (70 denier, $T_g = -20^\circ\text{C}$), polyethylene terephthalate (PET) knitted fabric (75 denier/72 filament), EDP knitted fabric (75 denier/72 filament) and two disperse dyes as listed in figure 2 and figure 3, namely CI Disperse Red 60 (low energy) and CI Disperse Red 167 (high energy) were applied in this study. Before dyeing, the spandex fabric was scoured, using 0.2g/l NaOH and 1g/l scouring agent (AZ-100) at 80°C for 20 min.

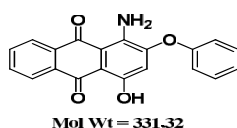


Figure 2. CI Disperse Red 60.

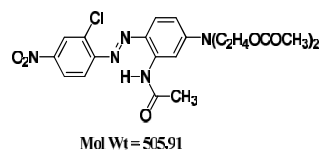


Figure 3. CI Disperse Red 167.

2.2. Dyeing

The EDP/spandex (80:20) and PET/spandex (80:20) blend were dyed at 90°C , 100°C , 110°C , 120°C and 130°C for 60 minutes in a dye bath of liquor ratio 20:1 using 1g/l dispersing agent and keeping pH 4.0-4.5 (acetic acid). The dye concentration was 1% (o.w.f). The dyeing was carried out using Daelim Starlet II Infrared Dyeing Machine (Korea).

2.3. Reduction clearing

The dyed samples were reduction cleared at 80°C for 20 min in a bath of sodium hydroxide (2g/l) and sodium hydrosulphide (2g/l).

2.4. Measurement

2.4.1. Partition ratio. After dyeing at different temperature, colorimetric properties using spectrophotometer (D65 illumination, 10° observer) and absorbance of extracted dye solution (40ml dimethylformamide per 0.1g of fabric) from dyed sample using UV-vis spectroscopy (Aligent 8453, made in USA) were measured to calculate the partition ratio.

$$\text{Partition ratio} = \frac{C_s}{C_f} \quad (1)$$

Where, CD_s and CD_f are the colour depth of spandex and PET or EDP respectively.

Again,

$$\text{Partition ratio} = \frac{A_s \times 4}{A_f} \quad (2)$$

Where, A_s and A_f are the absorbance of the extracted dye solution from spandex, PET or EDP. This case, equal weight of spandex and PET, and EDP were dyed.

2.4.2. Degree of dye exhaustion. The dye exhaustion on each blend was calculated by residual dye bath method as indicated in equation 3. Besides that, the exhaustion on each fabric as the dyeing time increased was determined by equation 4. This case, the absorbance of the extracted dyes was used to find out the amount of dye on each fabric using the Beer-Lambert law.

$$\% \text{ Exhaustion} = \left(1 - \frac{A}{A_0}\right) \times 100 \quad (3)$$

Where, A and A_0 are the initial and residual dye bath absorbance.

$$\% \text{ Exhaustion} = \left(\frac{D_f}{D_b}\right) \times 100 \quad (4)$$

Where, D_f is the amount of dye extracted from PET or EDP or spandex (in mg), D_b is the initial amount of dye in the dye bath (in mg).

3. Result and discussion

The partition ratios calculated by using equation (1) and (2) are shown in Figures 4 and 5. On the one hand, partition ratio on spandex and PET increases at low temperature but decreases when temperature is increased above 100°C. On the other hand, the EDP has exceptionally lowered the partition ratio of disperse dye on spandex and EDP blend at temperature below 100°C. Between the dyes, high energy dye has high partition ratio on spandex than low energy dye. After reduction clearing, the lowered partition ratio for both blends indicates that more disperse dye has been removed from spandex.

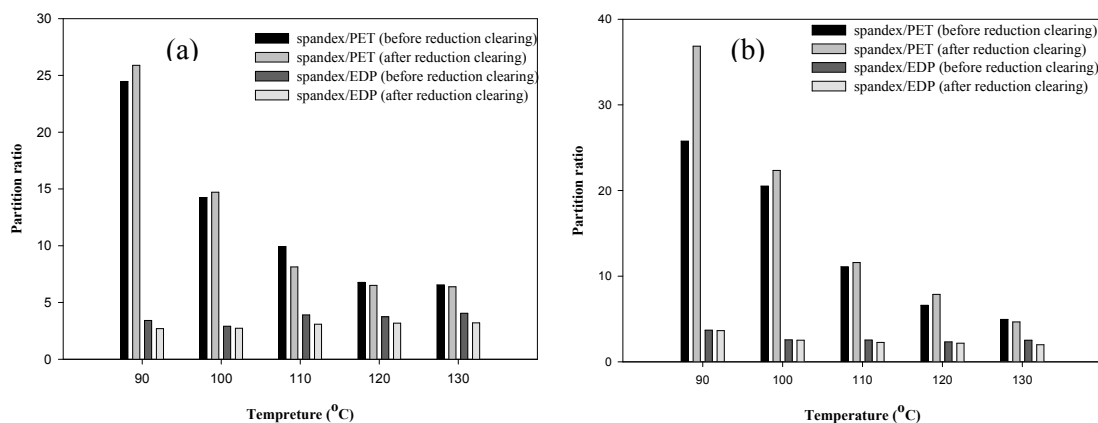


Figure 4. Partition ratio (a) CI Disperse Red 60 and (b) CI Disperse Red 167.

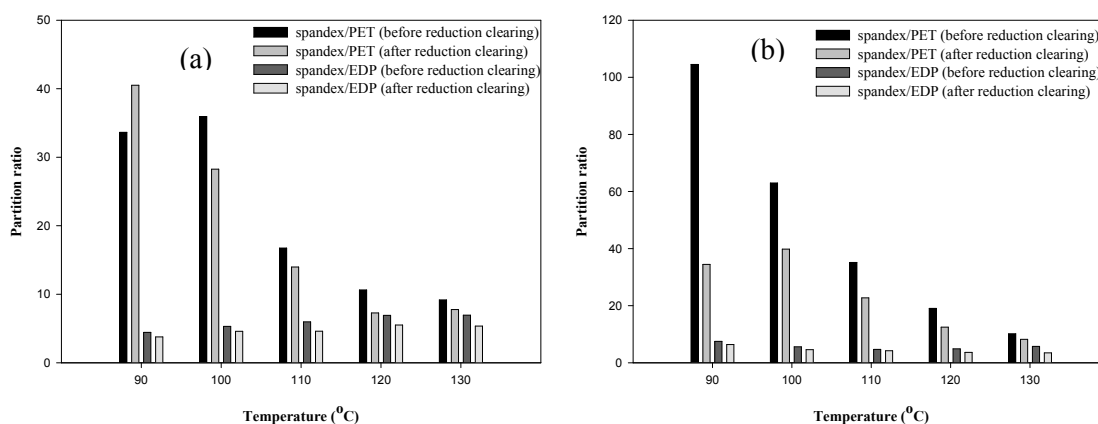


Figure 5. Partition ratio (a) CI Disperse Red 60 and (b) CI Disperse Red 167.

Color efficiency on the surface of PET/spandex and EDP/spandex blend is mainly determined by the PET and EDP respectively. Because the blend ratio of spandex is mainly very low and it is usually hidden inside the blend due to its elastic nature. To investigate the shade depth in details, the samples were collected separately as the dyeing time increased at different dyeing temperature and the color depth of each of the fabric for both dyes was measured. It is revealed from figure 6 and 7 that EDP exhibits better color depth at all dyeing temperature. It can also be seen that the color depth of EDP at 90°C is almost similar to the color depth of PET at 130°C, even though the spandex was blended with them. This result represents the excellent dye ability of the EDP/spandex blend at lower temperature. This unique behavior of the EDP/spandex blend can be explained by the co-polymer of polyethylene glycol group in EDP that created more flexibility and large surface area allowing faster dye uptake on the EDP at low temperature. It is also to be mentioned that the high energy dye confers two times higher color depth in EDP than low energy dye. It should be noted that as the dyeing time increases,

there is some variation in color depth in spandex at high temperature. This is mainly the uneven color distribution on the surface of spandex.

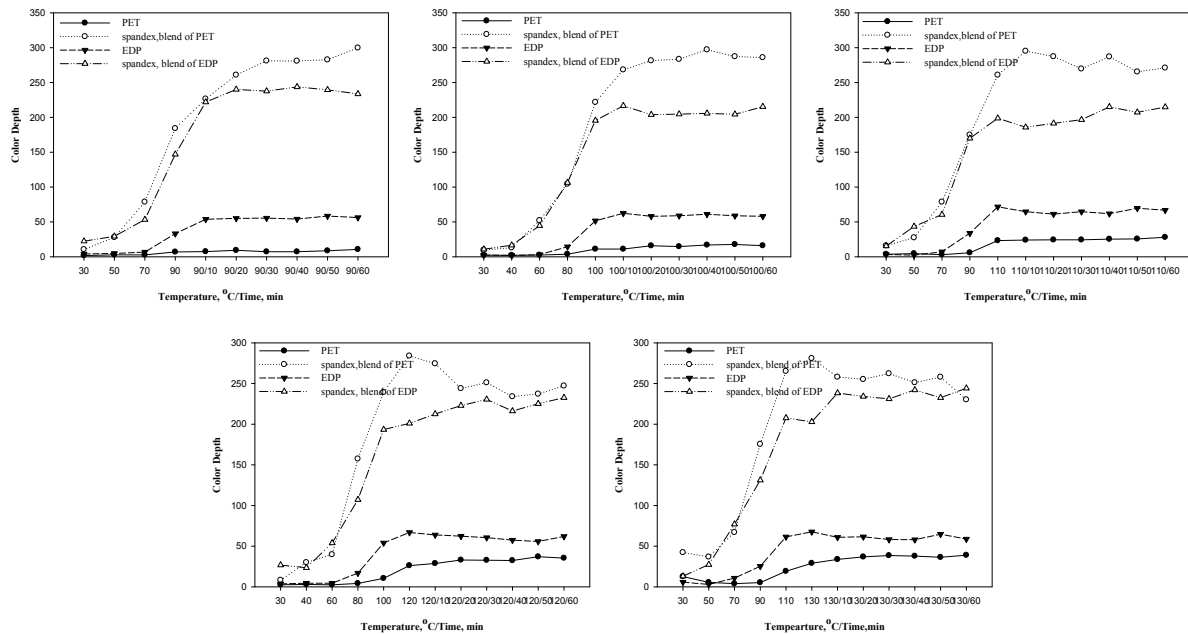


Figure 6. Color depths by applying CI Disperse Red 60 at different dyeing temperature.

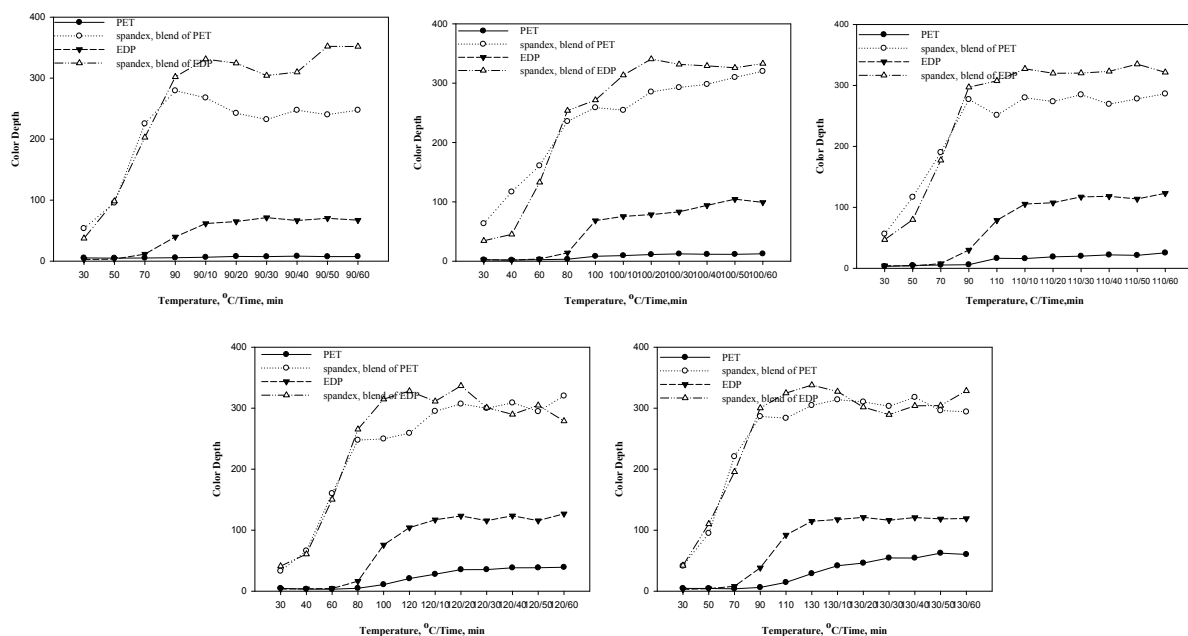


Figure 7. Color depths by applying CI Disperse Red 167 at different dyeing temperature.

Dye exhaustion was calculated in two different methods. Firstly, dye exhaustion on each blend by residual dye bath method. It shows that the PET/spandex has high exhaustion than EDP/spandex blend as illustrated in figure 8, the reason is not understood. Secondly, dye exhaustion was also calculated

for individual fabric as the dyeing time increased by using equation 4 that is depicted in figure 9 and 10 for two dyes respectively. At low temperature, the disperse dye is exhausted more on spandex than PET owing to the lower glass transition temperature of spandex. However, as the dyeing temperature is increased to 110°C, the dyes transfer from spandex to PET. But completely opposite behavior is observed in case of EDP/spandex blend. At the low temperature the disperse dye exhausts more on EDP than spandex and at high temperature the exhaustion on spandex is slightly increased but is still below than EDP. This observation may be related to the greater amount of amorphousness of EDP than PET. Indeed, the dye study shows that the high energy dye has more adsorption on spandex owing to its low adsorption on PET or EDP. That is more acute in case of PET/spandex blend. Low energy dye demonstrates opposite property. Exceptionally, the both dyes have low distribution on spandex when blended with EDP. This low exhaustion of disperse dye on spandex might be an effective indication of reduction of excessive stain of spandex. It is also to be mentioned that as the dyeing time increased the samples were collected and directly extracted without doing any washing. As a result each sample shows some variation in exhaustion at temperature below 80°C.

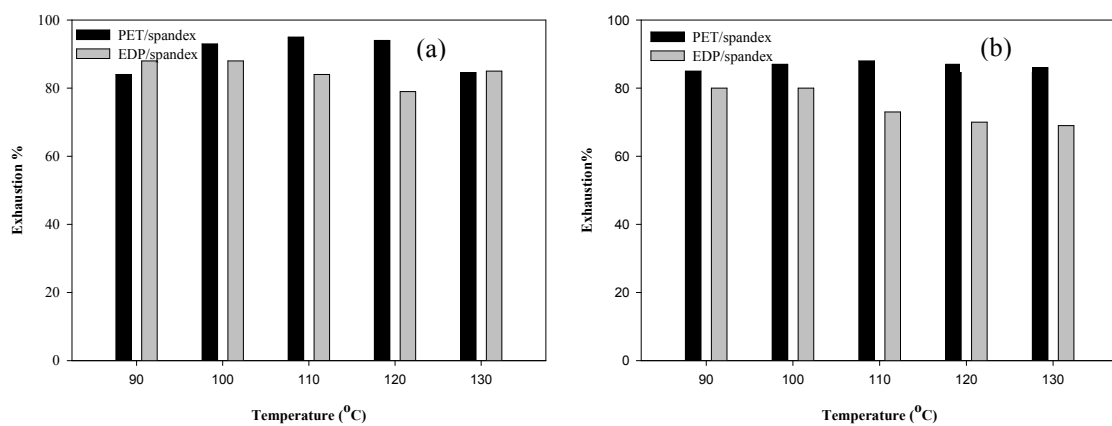


Figure 8. Residual dye bath Exhaustion (a) CI Disperse Red 60 and (b) CI Disperse Red 167.

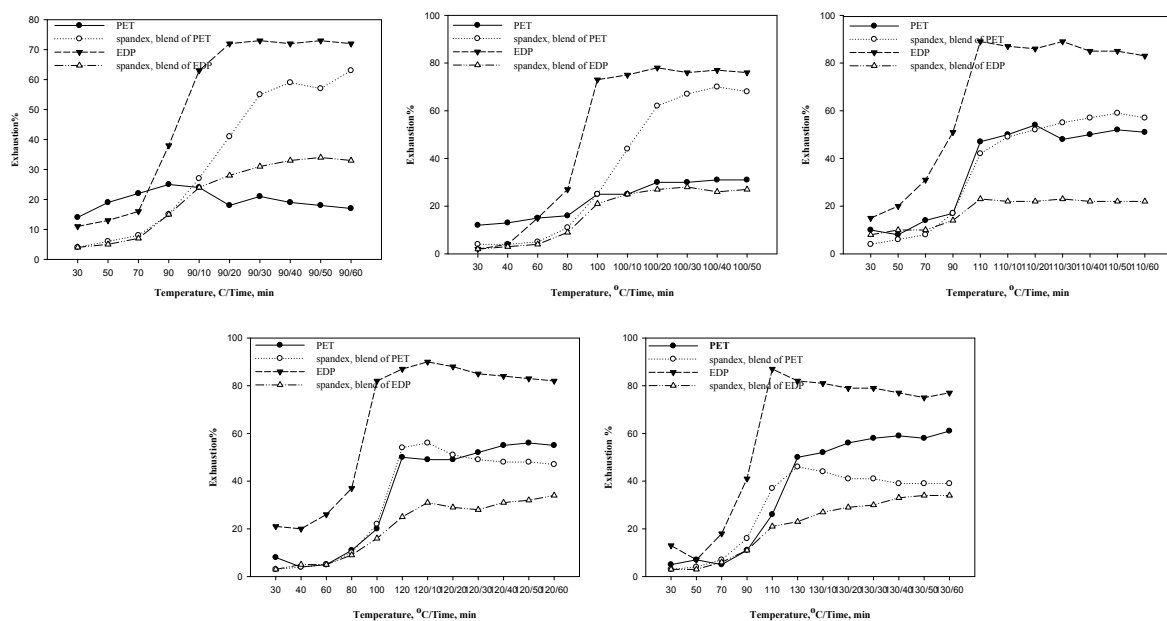


Figure 9. Dye Exhaustion on each fabric by applying CI Disperse Red 60.

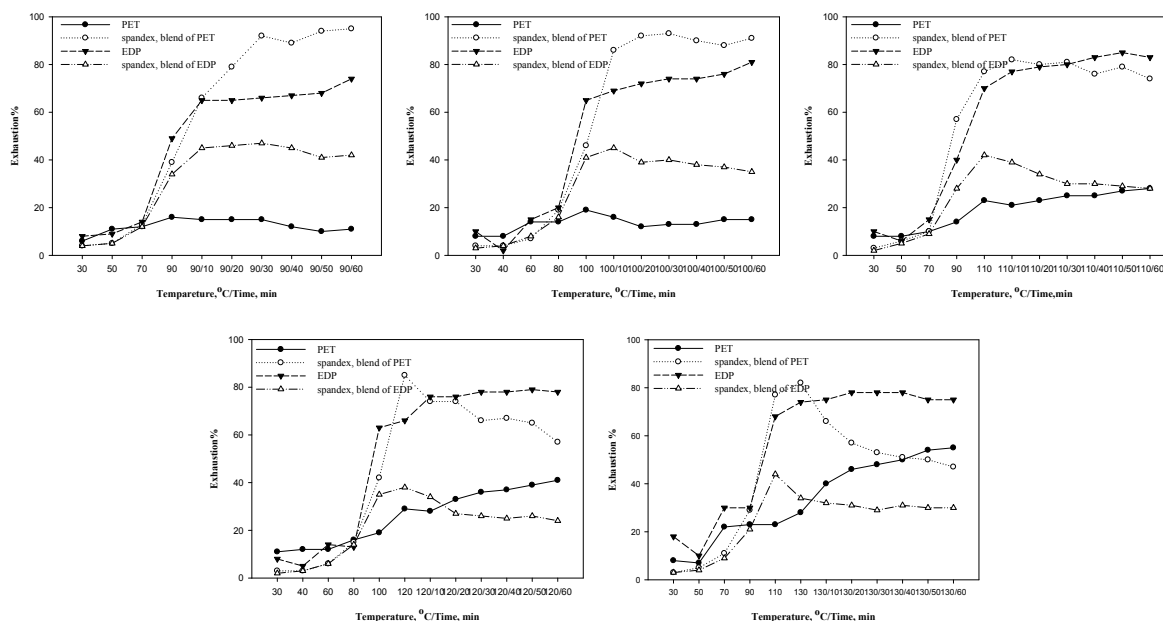


Figure 10. Dye Exhaustion on each fabric by applying CI Disperse Red 167.

4. Conclusion

The result of this study indicates that EDP/spandex blend exhibits excellent dyeing properties at temperature below 120°C, a temperature designed to keep the spandex flexible. The study again demonstrates that both dyes used in this study, exhausts less on spandex when blended with EDP but exhausts high when blended with PET. The EDP/spandex blend also needs low dye concentration to build up well at low temperature than PET/spandex blend. It is expected that the low dye concentration to build up and low exhaustion of disperse dye on spandex will reduced the excessive staining of the spandex and confers fastness rating that somewhat higher than the conventional PET/spandex blend.

Acknowledgements

This work was supported by the Industrial Technology Innovation Program (Advanced Technology Center, 10045679, Development of green-market deal with convergence textile products and high-function of breathable-waterproof PU film using plant-derived polyol) funded by the Ministry of Trade, industry & Energy(MI, Korea).

This work was supported by the Technological Innovation R & D Program (S2220477) funded by the Small and Medium Business Administration (SMBA, Korea).

This research was supported by Basic Science Research Program through the National Research Foundation of Korea(NRF) funded by the Ministry of Education(NRF-2014R1A1A2058758)

References

- [1] Qian H F and Song X Y 2009 *Coloration Technology* **125** 141-145
- [2] Choi J H and Towns A D 2001 *Coloration Technology* **117** 127-133
- [3] Qian H F and Song X Y 2007 *Dyes and Pigments* **74** 672-676
- [4] Qian H F and Song X Y 2009 *Coloration Technology* **125** 146-150
- [5] Suwanruji P, Chuaybamrung L, Suesat J, Hannongbua S, Taylor J A and Phillips D A S 2011 *Coloration Technogy* **128** 103-107