Coloration properties onto synthetic fibers using indigo

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Abstract

The indigo colorant has been widely used with its importance characteristics such as attracted shade and color fastness property. Indigo is nonionic but this can be reduced to water soluble anions in the course of dyeing. This work was determined whether the developed sparingly soluble leuco moiety can be used to the synthetic fibers or not. In this context, the aim of this study was to investigate the indigo dyeing behaviors on the fiber substrates and to optimize the dyeing conditions. The effect of the factors such as concentration of dye, dyeing temperature and pH on the level of color strength (K/S) was studied. The dyeing results showed that higher color strength (K/S) of the indigo dye uptake was achieved at higher temperatures. Acid leuco dyeing around pH 3-4 also showed higher dye. This application could provide excellent light and wash fastness at all depths of shade.

Keywords: Synthetic fiber, Indigo, Leuco, Color strength

1. Introduction

Natural colorants have been used for a long time, beginning in the Stone Age up to the 19th century. The situation dramatically changed when Perkin discovered the first synthetic dye, mauve, in 1856 [1,2]. The market for synthetic dyes increased rapidly. In dye houses, the application of disperse [3,4], reactive [5,6] and acid dyes [7,8] to synthetic fibers is the main study areas for many decades. In the years that followed, vat dyes [1,2] were attracted due to advantages of ease in application, variety in shade, superior fastness. The dyeing of synthetic fibers with different types of vat dyes [9,10] has been studying.

Vat dyes are sold as powder or paste pigment which produce nonionic dispersion in water. The dyes themselves are nonionic but they can be reduced to water soluble anions in the course of dyeing. In general, vat dyes have an affinity for cellulosic fibers [11] in its leuco form but it has a low affinity for synthetic fibers.

In this context, the aim of this work was to investigate the indigo vat dyeing behaviors on the synthetic substrates (PET, PTT/Spandex) and to optimize dyeing conditions [12]. The effect of the factors such as concentration of dye, dyeing temperature and pH on the level of color strength (K/S) achieved was investigated and determined.

2. Experimental

2.1 Materials

Synthetic substrates (PET, PTT/Spandex) were used in this experiment. The indigo vat dye and reducing agent were purchased from Aldrich. All other chemicals used in this study were of laboratory grade reagents.

2.2 Dyeing procedure

Fiber substrates were dyed in a sealed, stainless steel dye pots of 120cm^3 capacity in a laboratory-scale dyeing machine. Samples were placed in a 30℃ dye bath of 1:40 liquor ratio. After 30min at the 70℃, the temperature was raised until it reached 90℃ to 130℃ with 2℃/min and then continued for 60 min. The dyed samples were washed off using water and allowed to oxidize in the open air. Details of the dyeing process were illustrated in Fig. 1.

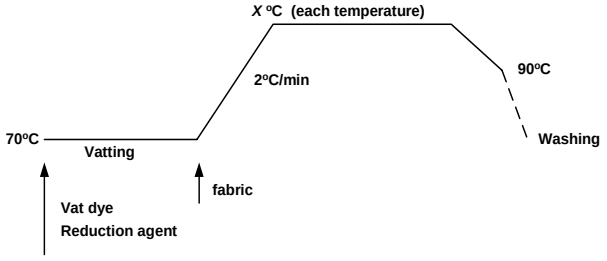

Fig. 1. Dyeing process with indigo dye.

2.3 Reduction clearing

After oxidation, the samples were reduction cleared to remove the loosely fixed dye on the surface of dyed fibers. The dyed samples were washed off and then rinsed in running tap water.

2.4 Color measurement

Colorimetirc data of the dyed fiber substrates were measured on a Datacolor SF 600 plus spectrophotometer. The relative color strengths (K/S) were determined using the Kubelka-Munk equation:

$$K/S = \frac{(1-R)^2}{2R}$$

where, K: coefficient of absorption of the dye at λ_{max}
S: coefficient of scattering at λ_{max}
R: Reflected light at wavelength λ_{max}

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3. Results and discussion

3.1 Effect of dyeing temperature

In order to examine the effects of dye concentrations and dyeing temperatures on the color strength, fiber substrates were dyed with indigo dye at dyeing temperatures (90℃ to 130℃). Fig. 2 illustrates the effect of dyeing temperatures on color strength of indigo dyeings.

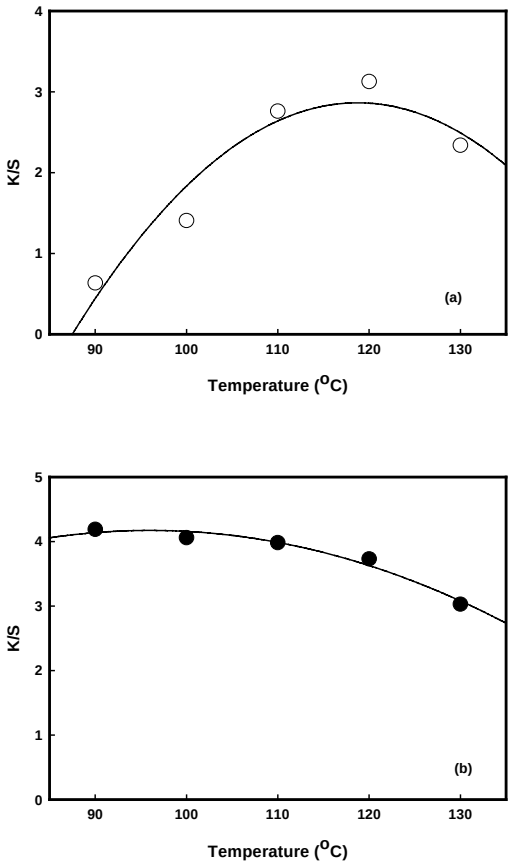


Fig. 2. Effects pf dyeing temperatures on color strength of indigo dyeings; (a) PET, (b) PTT/Spandex.

The results showed that color strength of the dyeings was dependent on the dyeing temperatures. In the case of PET, color strength of the indigo dyeings increased with increasing application temperature. In the case of PTT/Spandex, color strength of the indigo dyeings decreased with increasing application temperature. It is found that dyeing properties of indigo were influenced with the characteristics of fibers.

In Fig. 3, the dyeing properties of indigo using different dye concentrations were examined. The color strength of the dyed samples reached saturation values around the dye concentration of 8% and 6% o.w.f, respectively.

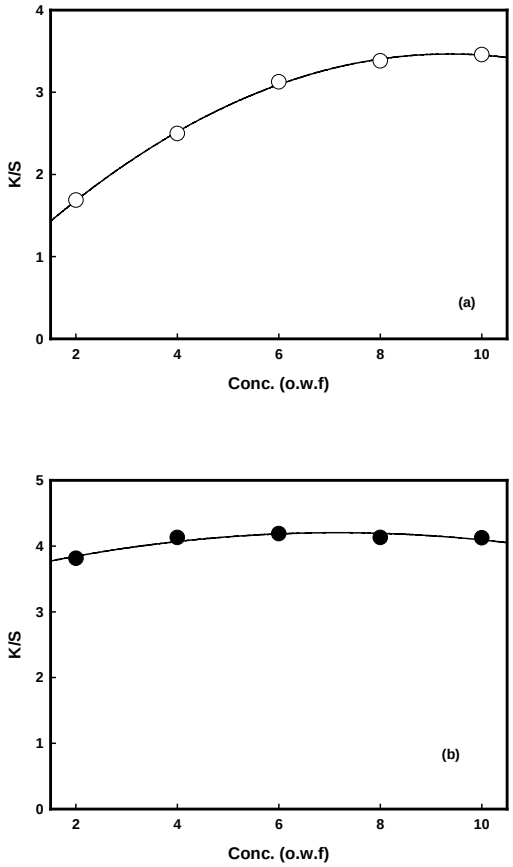


Fig. 3. Effect of dye concentrations on color strength of dyeings; (a) PET, (b) PTT/Spandex.

3.2 Effect of acid leuco dyeing

The typical structures of reduced indigo dye are showed in Fig. 4. The alkali leuco form, more hydrophilic property than the insoluble pigment form, has a high affinity for cellulosic fibers. However, the alkali leuco forms have a low affinity for synthetic fiber substrates, which is more hydrophobic than cellulosics. The hydrophilic cellulosic fibers could be dyed with indigo dissolved in an aqueous solution using a small amount of sodium hydrosulfite and sodium hydroxide. The synthetic fiber substrates could not be dyed well with the alkali leuco form under the same conditions. Thus, in the case of synthetic substrates, more hydrophobic dye moiety, namely acid leuco form may be suitable for higher dye exhaustion. In this context, to improve dye build-up a sparingly soluble acid leuco form was considered for dyeing approach to the hydrophobic fiber substrates. When acid is added into the dyebath, the alkali leuco form is converted into the sparingly water soluble acid leuco moiety which can be used in the dyeing of synthetic substrates.

The total K/S values (fk value) of the indigo dyeings obtained by the acid leuco form are shown in Figs. 5-6.

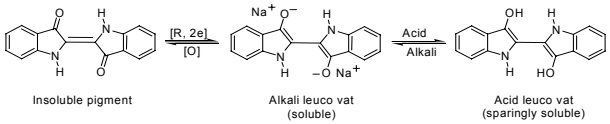
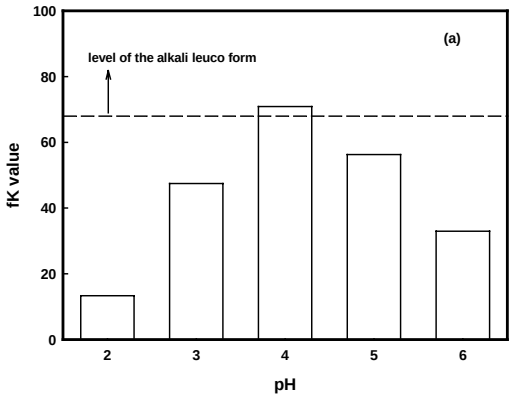


Fig. 4. Structural changes of indigo vat dye.



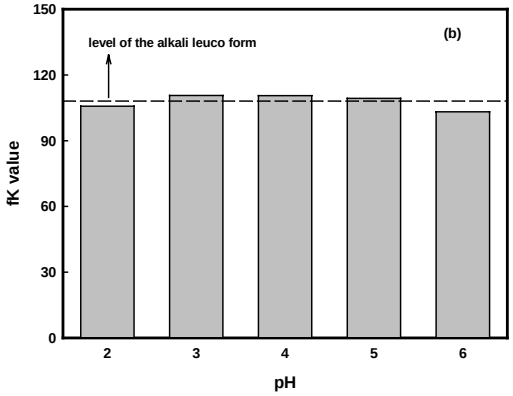
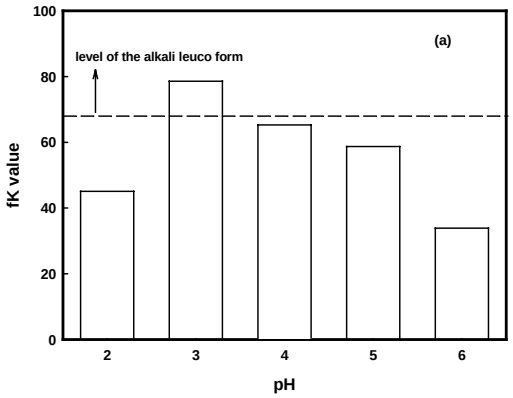


Fig. 5. Effect of acid leuco dyeing using acetic acid; (a) PET, (b) PTT/Spandex.



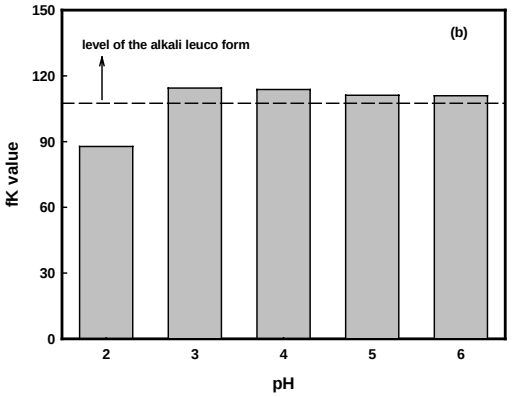


Fig. 6. Effect of acid leuco dyeing using formic acid; (a) PET, (b) PTT/Spandex.

The results showed different dye uptake behaviors from added acid types. In the case of acid leuco dyeing using acetic acid, it showed higher dye uptake at the pH 4 and pH 3-4, respectively. The fk values were similar those of alkali leuco dyeing. Other acid leuco dyeing using formic acid, it showed higher dye uptake at the pH 3 and pH 3-4, where the fk values were higher than those of alkali leuco dyeings. In this context, the dyeing application using acid leuco form on to synthetic fiber substrates is a considerable alternative to increase dye uptakes.

4. Conclusions

In this work, the dyeing properties using indigo vat dye were examined. The effect of dyeing temperatures showed that color strength of the dyeings was dependent on the dyeing temperaturs. In the case of the effect of acid leuco dyeing, dispersion of the acid leuco moiety of indigo had behaved as hydrophobic dyes and dyed the synthetic substrates in a satisfactory manner.

Acknowledgements

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References

[1] Sung-Hoon Kim, Young-A Son, Jin-Suk Bae, Dye Chemistry, Green Book Company inc., 2005.

[2] F. Govaert, E Temmerman, P. Kiekens, Development of voltammetric sensor for the determination of sodium dithionite and indanthrene/indigo dyes in alkaline solutions, Analytica Chimica Acta, 385(1-3), pp.307-314 (1999).

[3] Tae-Soo Choi, Yoshio Shimizu, Hirofusa Shirai, Kunihiro Hamada, Disperse dyeing of polyester fiber using Gemini surfactants containing ammonium cations as auxiliaries, Dyes and Pigments, 50(1), pp.55-65 (2001).

[4] A. Ferri, M. Banchero, L. Manna, S. Sicardi, Dye uptake and partition ratio of disperse dyes between a PET yarns and supercritical carbon dioxide, J. of Supercritical Fluides, 37(1), pp.107-114 (2006).
[5] S. M. Burkinshaw, K. Gandhi, The dyeing of conventional and microfibre nylon 6,6 with reactive dyes. Part2. α-bromoacrylamido dyes, Dyes and Pigments, 33(44), pp.259-280 (1997).
[6] S. M. Burkinshaw, Young-A Son, S. N. Chevli, The fastness to repeated washing of reactive dyes and pre-metallised acid dyes in nylon 6,6, Dyes and Pigments, 45(1), pp.43-49 (2000).
[7] S. M. Burkinshaw, K. D. Maseka, Improvement of the wash fastness of non-metallised acid dyes on conventional and microfibre nylon 6,6, Dyes and Pigments, 30(11), pp.21-42 (1996).
[8] Young-A Son, Jin-Pyo Hong, Tae Kyung Kim, An approach to the dyeing of polyester fiber using indigo and its extended wash fastness properties, Dyes and Pigments, 61(3), pp.263-272 (2004).
[9] Hea-Young Jang, Ho-Jung Kim, Mun Cheul Lee, Dyeing properties of synthetic fibers with indigoid vat dye, J. of Korea Society of Dyers and Finishers, 13(5), pp.41-47 (2001).
[10] Katushi Kunttou, Setsuaki Hongyo, Shingo Maeda, Dyeing polyester fabrics with indigo, Textile Research J., 75(2), pp.149-153 (2005).
[11] T. Bechtold, A. Turcanu, S. Geissler, E. Ganglberger, Process balance and product quality in the production of natural indigo from Polygonum tinctorium Ait. Applying low-technology methods, Bioresource Technologym 81(3), pp.171-177 (2002).
[12] Young-A Son, Tae Kyung Kim, The application of non-ionic vat dye to polyester fiber: Practical aspects and preliminary studies, J. of Korea Society of Dyers and Finishers, 15(1), pp.23-29 (2003).