

〈Research Paper〉

Reactive Dyeing Properties of Cotton/hemp Blend

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Abstract— A mixed bi-functional reactive dye has been applied to the cotton and the cotton/hemp blend and their dyeing and fastness properties were compared. The cotton/hemp blend exhibited higher exhaustion values and better build-up property than cotton, presumably due to the lower crystallinity. Hence, the reproducibility of dyeing of hemp is expected to be excellent. Fastness properties of reactive dyes on cotton and cotton/hemp blend are found to be almost identical. The results obtained suggest that hemp in cellulosic fabric could be used as an important alternative to universal cotton in cellulose fabrics.

Keywords: *reactive dye, dyeing properties, hemp, cotton, blend, fastness properties*

1. Introduction

Hemp grows well without herbicides, fungicides, or pesticides. The production of cotton, on the other hand, consumes almost half of the agricultural chemicals used on American crops. Hemp bast fibers are one of the longest natural soft fibers. They are longer, stronger, more absorbent, more mildew-resistant, and more insulative than cotton. This means that hemp will keep you warmer in winter and cooler in summer than cotton. Hemp is more effective at blocking the sun's harmful ultraviolet rays. The nature of hemp fibers makes them more absorbent to dyes, which coupled with hemp's ability to better screen out ultraviolet rays, means that hemp material is less prone to fading than cotton fabrics are. Like cotton, hemp can be made into a variety of fabrics, including high quality linen. When blended with materials such as cotton, linen, and silk, hemp provides a sturdier, longer lasting product, while maintaining quality.

In the present work, a mixed bi-functional reactive dye has been applied to the cotton and the cotton/hemp blend fabric and their dyeing and fastness properties compared.

2. Experimental

2.1 Materials

Cotton fabrics (Single jersey, 30s') and cotton/hemp (80/20) blend fabrics (Single jersey, 30's) were provided by HEMPLEEKOREA (South Korea).

The commercial sample of mixed bi-functional reactive dye Sunfix Supra Red S3B 150% (C.I. Reactive Red 195, a mixed bifunctional(2-chloro-4-vinylsulphonyl anilino-triazine) type, Oh Young Industry) was used as such without any purification prior to use. A commercial sample of soaping agent (SNOGEN CS-940N, non-ionic) was supplied by Daeyoung Chemicals. All other reagents used were of laboratory reagent grade.

2.2 Dyeing

A 40 ml dyebath, suitable for a 2.0 g sample (material-to-liquor ratio 1:20) containing a reactive dye and Glauber's salt was prepared. Dyeing was carried out at 60°C for 60 min using an IR laboratory dyeing machine (Starlet-2, DaeLim Starlet Co. Ltd., Korea). The dyed fabric was rinsed and then treated with soaping agent (1g/l) for 10 min at 95°C.

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The cellulose fabrics were dyed at various dyebath conditions using salt concentration, alkali concentration, and dye concentration to investigate their effects on the dyeing properties. Exhaustion behavior of reactive dyes on the fabric was also investigated by monitoring the exhaustion values of dyed fabrics as the dyeing proceeds. The extent of dye exhaustion (%) achieved for an appropriate dye concentration on each of the two types of fabric was determined by using the following equation :

$$\text{Exhaustion (\%)} = \frac{A_b - A_a}{A_b} \quad (1)$$

where, A_a is the absorbance of dyebath after dyeing ; and A_b , the absorbance of dyebath before dyeing.

The Fixation (%), percentage of dye exhausted which is covalently bonded to the fiber was determined as follows; at the end of dyeing, the dyed fabric was cut into two pieces (1.25g each) ; one piece was allowed to dry in the open air and the other piece was treated in an aqueous solution containing Sandozine NIE (5.0 g/l) and Na_2CO_3 (2.5 g/l), using a 50:1 liquor (62.5 ml of liquor) ratio at 98°C for 30 min and finally rinsed thoroughly in tap water before being allowed to dry in the open air¹⁾ The color strength (K/S) of the each of the two dry, dyed samples is measured using spectrophotometer and the extent of apparent fixation (%) achieved is calculated using following Eqn 2 :

$$F\% = 100 \times \frac{(K/S)_2}{(K/S)_1} \quad (2)$$

where, $(K/S)_1$ = K/S values of dyed sample before washing

$(K/S)_2$ = K/S value of dye sample after washing

F% = Degree of fixation of absorbed dye

2.3 Fastness test

The cellulosic fabrics were dyed (1/1 standard depth), treated with soaping agent and then heat set (170°C , 40 sec) in order to test the color fastness. The color fastness was determined according to International Standards: ISO 105 C06/C2S (color fastness to washing), ISO 105 E04 (color fastness to

perspiration) and ISO 105 X12 (color fastness to rubbing). Staining and change in colour were assessed using grey scales.

3. Results and Discussion

Figs 1-6 show the dyeing properties of cotton and cotton/hemp blend. The variation in dye yield has been studied with the variation in salt concentration and alkali concentration to compare their effect on the shade of hemp and cotton.

The molecules of reactive dyes are smaller than those of direct dyes and their smaller size is accompanied by a correspondingly lower substantivity. The molecules of direct dyes are deliberately made large so as to build up the physical attraction between fabric and dye, thus making them more substantive. Much smaller molecules may be suitable for use as reactive dyes because one covalent bond is about thirty times as strong as one van der Waals bond²⁾.

3.1 Effect of salt concentration on dyeing properties

Reactive dyes are usually applied with the addition of electrolyte and the extent to which reactive dyes are affected by the addition of electrolytes to the dyebath is known as salt sensitivity³⁻⁸⁾. The addition of electrolyte increases the strike rate of the dye. The commonly used electrolytes are Glauber's salt (sodium sulphate) and common salt (sodium chloride). When cellulose is immersed in a solution of reactive dye, it absorbs dye from the solution until equilibrium is attained and at this stage, most of the dye is taken up by the fabric. Cellulose carries a negative charge in pure water. As the dye is also anion, there is an electrostatic anion-anion repulsion between dye and cellulose. Therefore, the probability of the dye adsorbing onto the fabric (level of substantivity) is reduced. The substantivity of the dye for cellulose is the proportion of dye absorbed by the fabric compared with that remaining in the dyebath. By adding inert electrolyte such as common salt or Glauber's salt to the dyebath, this electrostatic barrier (Donnan Potential) can be largely suppressed, facilitating dye/fabric contact and allowing better interaction of van der Waals forces ; this improves the substantivity.

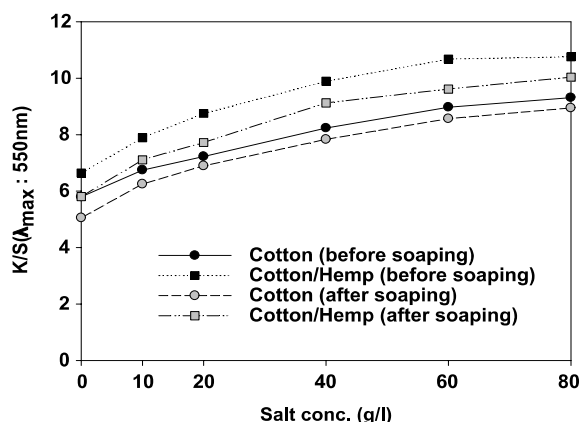


Fig. 1. Color strength of cotton and cotton/hemp blend at various salt concentrations (1%owf dyeing, Na_2CO_3 20g/l).

The diffusion coefficient of dye is therefore a function of both dye and electrolyte concentration^{4,9)}. Fig. 1 shows that the K/S values of dyed fabrics increases with the increase in salt concentration. The dye exhaustion of reactive dye is linear function of salt concentration particularly at lower dye concentrations within the cellulose in the presence of a fixed amount of added dyes although the slope decreases with the increase in salt concentration. It is considered that the initial rapid rise in K/S values is due to the response of dye to the lowering of electrical potential barrier to diffusion as the concentration of electrolyte increases. The mixed bi-functional reactive dye shows high exhaustion of dyeings, irrespective of the amount of salts applied. The mixed bi-functional reactive dyes were designed primarily for exhaust dyeing with the triazinyl group being used to enhance the substantivity (30-60%) of this type of dye. Also, the vinylsulphone group in the mixed bi-functional reactive dye enhances the substantivity for cellulose as the precursor groups lose their ionic charge by 1,2-elimination while the triazinyl group itself has relatively high substantivity for cellulose^{5,10)}.

It is also evident from Fig. 1 that the color strength of dyed cotton/hemp blend is higher than that of cotton for the mixed bi-functional reactive dye used. The excellent dyeing yields on hemp could be presumably ascribed to the lower crystallinity values. As a useful generalization, the fabrics may be regarded as structures in which there is a spread of molecular order, ranging from highly ordered crystalline domains to disordered amorphous regions.

The strength originates in the crystalline material while the amorphous material provides the flexibility. Therefore, the fabric properties, including dyeing properties, vary depending upon the relative degrees of order and disorder in the structure (often described as the crystalline/amorphous ratio) and also molecular alignment (degree of orientation), i.e. lower orientation and crystallinity mean a higher rate of dye diffusion with these fabrics.

3.2 Effect of alkali concentration on dyeing properties

Fig. 2 shows the fixation (%) of adsorbed dyes on cotton and cotton/hemp blend. The fixation (%) values of the dye used were dramatically increased with the addition of alkali and reached to the saturation levels around 20g/L of alkaline concentration values.

Fig. 3 shows the color strength of cotton and cotton/hemp blend at various alkali concentrations.

The K/S value on cotton/hemp blend fabric is higher than that on cotton suggesting hemp has better dyeability compared with cotton. This result is also consistent with that of salt effect. Especially, in case no alkali addition, K/S values were dramatically decreased after soaping due to the least covalent bond formation between fibers and reactive dyes. The exhaustion values of the dye used were reached to the saturation levels around 20g/L of alkaline concentration values.

3.3 Dyeing behaviors

Fig. 4 shows the exhaustion behavior of reactive dye on cellulose fabrics during dyeing. As expected, the dyeing rate of two cellulose fabrics is not the same because of their supramolecular structures. Different dyeing rates, brought about by the difference in physical structure, are clearly of practical importance. Predictably, hemp shows higher exhaustion than cotton, presumably due to the lower crystallinity. The crystallites lie preferentially parallel to the fiber axis and are separated by regions of lower order and intermicellar spaces. The average size of the crystallites and the quantitative ratio of crystallites to regions of lower order are strongly fabric-specific.

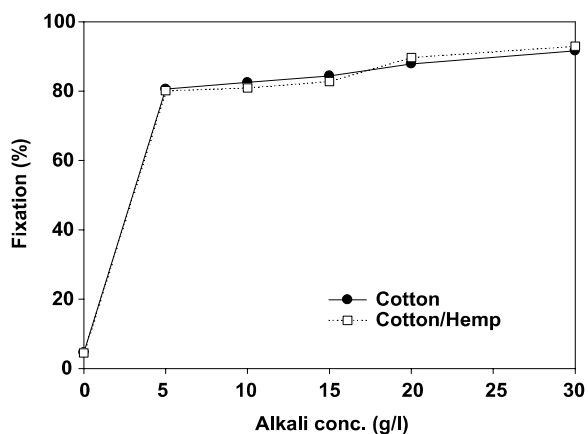


Fig. 2. Alkali concentration effect on the fixation of cotton and cotton/hemp blend (1%owf dyeing, Na_2SO_4 40g/l).

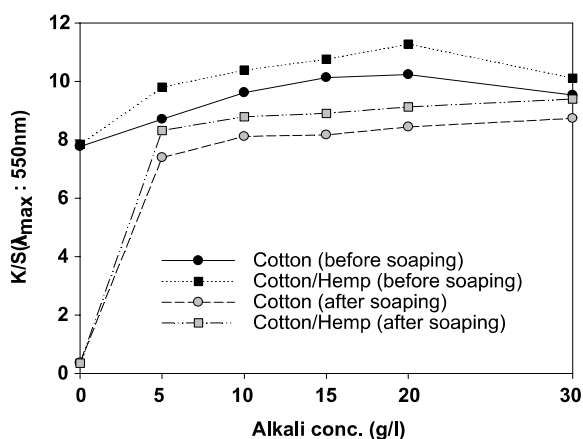


Fig. 3. Color strength of cotton and cotton/hemp blend at various alkali concentrations (1%owf dyeing, Na_2SO_4 40g/l).

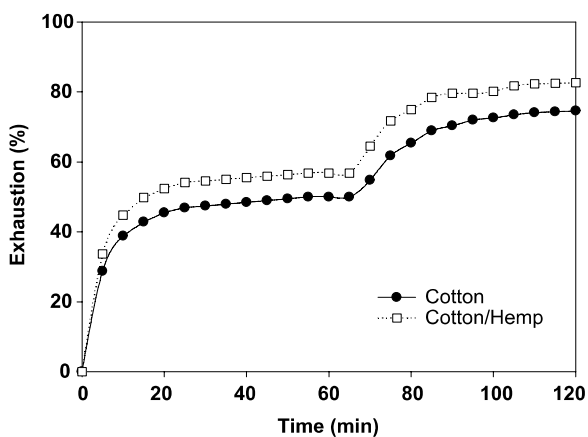


Fig. 4. Exhaustion behaviors of cotton and cotton/hemp blend (1%owf dyeing, Na_2SO_4 40g/l, Na_2CO_3 20g/l).

Only water-swollen intermicellar spaces and regions of lower order of the fabric are accessible to large reactive dye molecules. It is completely impossible for a dye to diffuse into the highly

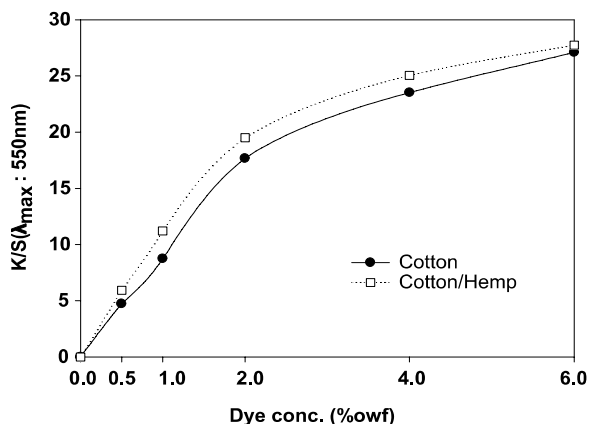


Fig. 5. Build-up property of a reactive dye on cotton and cotton/hemp blend (Na_2SO_4 40g/l, Na_2CO_3 20g/l).

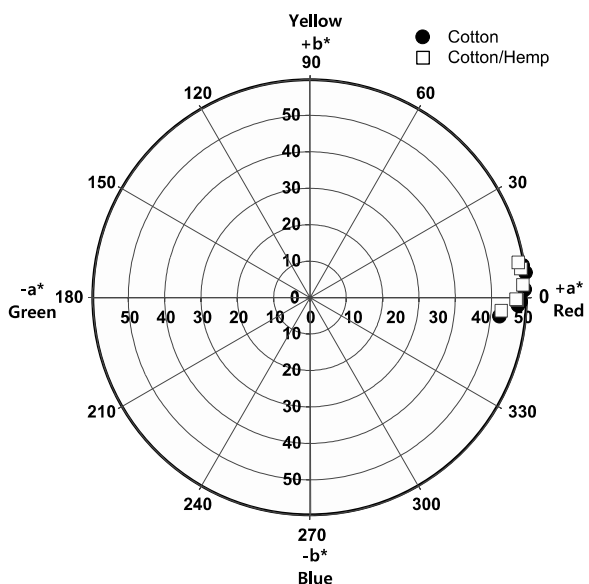


Fig. 6. Color properties of cotton and cotton/hemp blend at various dye concentration (Na_2SO_4 40g/l, Na_2CO_3 20g/l).

oriented crystallites. Dyeing, therefore, only proceeds at the outer walls of the crystallites and in the non-oriented cellulose.

Further evidence that the dyeability of hemp is better than that of cotton has been provided by the results of build-up properties obtained for the mixed bi-functional reactive dye.

Fig. 5 shows that the hemp component dyes to a deeper shade than cotton.

Fig. 6 shows the color properties of cotton and cotton/hemp blend at various dye concentration. Their color coordination value were almost identical in CIE a^*-b^* color coordinate.

3.4 Fastness properties

Table 1 shows that the wash fastness and perspiration fastness of 1/1 standard depth dyeings of the reactive dye on cotton/hemp are similar to that of comparable depth dyeings on cotton. Table 2 also reveals that the perspiration fastness of the 1/1 standard depth dyeing of C. I. Reactive Red 195 on cotton/hemp was identical to that of the dye on cotton. In the case of rubbing fastness (Table 3), although the wet rubbing fastness of the reactive dyes on cotton was slightly better than on cotton/hemp blend, the dry rubbing fastness figures were excellent (a rating of 5), irrespective of fabrics.

Table 1. Wash fastness of cotton and cotton/hemp blend fabrics

Fabric	Cotton		Cotton/Hemp	
	Change	Staining	Change	Stainig
Wool	4-5	4-5	4-5	4-5
Acryl	4-5	4-5	4-5	4-5
PET	4-5	4-5	4-5	4-5
Nylon	4-5	4-5	4-5	4-5
Cotton	4-5	4-5	4-5	4-5
Acetate	4-5	4-5	4-5	4-5

Table 2. Perspiration fastness of cotton and cotton/hemp blend fabrics

Fabric	Cotton		Cotton/Hemp	
	Alkali	Acid	Alkali	Acid
Wool	4-5	4-5	4-5	4-5
Acryl	4-5	4-5	4-5	4-5
PET	4-5	4-5	4-5	4-5
Nylon	4-5	4-5	4-5	4-5
Cotton	4-5	3-4	4-5	4
Acetate	4-5	4-5	4-5	4-5

Table 3. Rubbing fastness of cotton and cotton/hemp blend fabrics

Fabric	Cotton		Cotton/Hemp	
	Dry	Wet	Dry	Wet
Staining	5	3-4	5	3

4. Conclusions

The dyeing properties of a cotton/hemp blend with the mixed bi-functional reactive dye were found to be excellent in comparison to cotton. Cotton/hemp blend exhibited higher exhaustion values and better build-up property than cotton, presumably due to the lower crystallinity. Hence, the reproducibility of dyeing of hemp is expected to be excellent. Fastness properties of reactive dyes on cotton and cotton/hemp blend are found to be almost identical. The results obtained suggest that hemp in cellulosic fabric could be used as an important alternative to universal cotton in cellulose fabrics although more detailed studies on the hemp is necessary before any definite conclusions can be drawn.

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