Application of wool reactive dyes for hair coloration

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Abstract In this study, the low temperature dyeing properties of wool reactive dyes were investigated for the feasibility study of hair coloration using wool-reactive dyes. The low temperature (30°C, 40°C) wool reactive dyeing properties were compared to the conventional temperature (80°C) wool reactive dyeing and their dyeing properties were compared with those at high temperature. The experiment results showed that the application of low temperature wool reactive dyeing to hair coloration is sufficiently feasible in terms of dyeability and shampooing fastness.

1. Introduction

The reactive dyes are unique among other dyes in that they are covalently bonded to the substrate (Figure 1), that is, the dye and fiber substrate form a bond of shared electrons. The energy required to split this bond is of the same order as that required to split carbon-carbon bonds in the substrate itself—hence the high degree of wet fastness observed with these dyes.

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![Figure 1. Chemical structure of reactive dyed wool](image)

2. Experimental

2.1. Material

![Figure 2. Wool reactive dyes used in present study](image)

(a) CI Reactive Yellow 39  (b) CI Reactive Red 84  (c) CI Reactive Blue 69

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Scoured twill woven wool fabrics were used for the low temperature reactive dyeings. The wool reactive dyes (Figure 2, CI Reactive Yellow 39, CI Reactive Red 84 and CI Reactive Blue 69) and leveling agent (Albegal B) were supplied by Huntsman. Sodium sulfate, ethyl lactate and the other chemicals were all reagent grade.

2.2. Dyeing
A 40 ml dyebath, suitable for a 2.0 g sample of wool fabric, containing dyes (2.0% owf), levelling agent (1.0%owf), sodium sulfate (10%owf) and acid donors (ethyl lactate 0.2% v/v) for pH control was prepared. Dyeing was performed for 5 min at 30, 40 and 80 °C in an laboratory dyeing machine (DLS-6000, Daelim Starlet Co. Ltd). The color strength ($f_k$) and CIELAB values of the dyed fabrics were measured using a spectrophotometer interfaced with a personal computer. To evaluate the color fastness of the wool reactive dyeings, shampoo fastness test was carried out for 5min at 40°C.

2.3. Evaluation of leveling properties
24 spots of the dyed wool were measured with a spectrophotometer, and the levelness parameter (L) was determined using the given equation as follows;

$$L = 1.2 \times (2.0 - \ln U), \quad (U \geq 0.3114)$$  \hspace{1cm} (1)

$$L = 5.0 - 1.2 \times \exp(7/6) \times U, \quad (U < 0.3114)$$  \hspace{1cm} (2)

where $U = \sum S_r(\lambda) \times V(\lambda)$

$S_r(\lambda) = \text{Relative sample standard deviation of } (K/S)_\lambda$

$V(\lambda) = \text{Spectral luminous function}$

2.4. Shampoo fastness test
In order to evaluate the color fastness of the wool reactive dyeings, shampoo fastness test was carried out for 5 min at 40°C. After 5 times shampooing, color loss (reduction in color strength, $f_k$) during shampooing was determined as follows;

$$\text{Color loss(\%)} = 100 \times \left( \frac{f_{k,0} - f_{k,5}}{f_{k,0}} \right)$$  \hspace{1cm} (3)

where, $f_{k,0} = f_k \text{ before shampooing}$

$f_{k,5} = f_k \text{ after 5th shampooing}$

3. Results and discussion

![Figure 3. Color strength ($f_k$) of wool reactive dyeing at various temperatures](image-url)
Figure 3 shows the dyeability of wool reactive dyeings at various dyeing temperatures. The color strength \( f_k \) of the low temperature \( (40^\circ C) \) dyeing exhibited around 15–20 while that of the conventional high temperature \( (80^\circ C) \) dyeing was 70-155. The addition of leveling agent improved the dyeability of the wool-reactive dyeing at each dyeing temperature, which is ascribed to the amphoteric characteristics of the leveling agent (Figure 4). The amphoteric group overcome the tippy dyeing properties of wool by forming dye-surfactant complexes which at lower temperatures probably exhaust more evenly and extensively onto the surface of the wool fiber than does the dye alone. As the dyebath temperature is raised the dye-surfactant complex breaks down, allowing the dye to penetrate and react with the fiber.

Figure 4. Leveling agent (Albegal B) effect on the dyeability of wool reactive dyeing, from left to right, yellow, red and blue

However, as shown in Table 1, no significant differences in the levelness of the dyed samples in our laboratory scale dyeing were detected. The levelness achieved was in the range of 4.2-4.9.

| Dye                  | Temperature | With Albegal B | Without Albegal B |
|----------------------|-------------|----------------|-------------------|
| CI Reactive Yellow 39| 80°C        | 4.8            | 4.8               |
|                      | 40°C        | 4.9            | 4.9               |
|                      | 30°C        | 4.9            | 4.9               |
| CI Reactive Red 84   | 80°C        | 4.6            | 4.4               |
|                      | 40°C        | 4.7            | 4.6               |
|                      | 30°C        | 4.5            | 4.5               |
| CI Reactive Blue 69  | 80°C        | 4.3            | 4.2               |
|                      | 40°C        | 4.5            | 4.3               |
|                      | 30°C        | 4.5            | 4.5               |

Figure 5 shows gradual decrease in color strength with increase in number of shampooing. In yellow, 15.38% of color loss showed after 5th shampooing, at 30°C wool dyeing. At 40°C wool dyeing, yellow color strength decreased 9.56% after 5th shampooing. About red, 22.17% of color loss at 30°C wool dyeing, and 19.61% loss at 40°C wool dyeing. Blue showed 18.85% loss at 30°C wool dyeing, and 17.03% loss at 40°C wool dyeing.
Conclusion
In this study, the low temperature dyeing properties of wool reactive dyes were investigated for their application to hair coloration. 14.2~20.5% color strength of high temperature (80°C) dyeing was achieved by low temperature reactive dyeings at 40°C. Color loss (%) during repeated shampooings up to 5 was in the range of 9.56~22.14%. The overall experiment results showed that the application of low temperature wool reactive dyeing to hair coloration sufficiently feasible, even though further studies on the application of wool reactive dyes on human hair dyeing are necessary before any definite conclusions can be drawn.

References
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