# Influence of Low-Temperature Dyeing Process on Physical Properties and Surface Morphology of Cashmere Fibers

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**ABSTRACT**

A low temperature dyeing process of cashmere has the advantages of saving energy and causing less damage to fibers. In this paper, the tensile properties of dyed cashmere by low-temperature dyeing and conventional dyeing were tested using a single fiber tensile tester. The surface morphologies of raw cashmere and dyed cashmere were observed by scanning electron microscopy (SEM). The SEM pictures show that the damage of the surface scale of cashmere by low the temperature dyeing process was much less than by the conventional dyeing process, and the tensile strength of deyed cashmere fiber by low-temperature dyeing was found to be high. Light-color and medium-color cashmere fibers dyed with Pula dye by low-temperature dyeing have good color fastness.

**Keywords:** cashmere; low-temperature dyeing; tensile property; color fastness; surface morphology

## INTRODUCTION

Cashmere fiber has soft and good handle. In textile and dyeing processes, it is very important to maintain the good properties of original cashmere fiber. During the dyeing process, the dense scale layer of cashmere fibers prevents the dye from adsorbing on the fibers and entering into the inside of the fiber[1-2], so the high temperature is usually used in conventional dyeing process in order to improve the diffusion rate of dyes. However, high-temperature dyeing not only requires considerable energy, but also influences fiber handle [3-4]. In this paper, the properties and color fastness of dyed cashmere by low-temperature process and conventional dyeing process were investigated.

## EXPERIMENTAL

### Materials

Cashmere fiber: Inner Mongolia cashmere fibers were selected, and fiber mean diameter was 14.6 μm.

Dye stuff: Pula red B, Pula yellow GN, and Pula Brilliant Blue RAWL were used for cashmere dyeing.

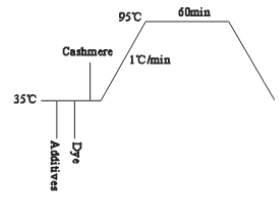
Additives: cashmere low temperature dyeing additive, Albegal set, acetic acid, and ammonium sulfate were used in the dyeing.

### Dyeing Method

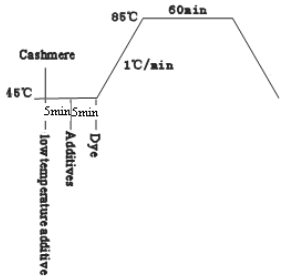
Pula red B, Pula yellow GN, and Pula brilliant blue RAWL was matched with each other to obtain light, medium and dark color. Through orthogonal experiment, the dyeing conditions of light, medium and dark colors were determined (as shown in *Table I*).

### Dyeing Process Curve

The dyeing curves for the high-temperature dyeing process and the low-temperature dyeing process are shown in *Figure 1*.




(a) High-temperature dyeing curve




(b) Low-temperature dyeing curve

FIGURE 1. Dyeing process curve.

TABLE I. Dyeing conditions of cashmere fibers.

| Material | light color | | medium color | | dark color | |
|---|---|---|---|---|---|---|
| | Conventional | Low -temperature | Conventional | Low -temperature | Conventional | low -temperature |
| Pula red B | 0.1 | 0.1 | 0.7 | 0.7 | 2 | 2 |
| Pula yellow GN | 0.1 | 0.1 | 0.2 | 0.2 | 1 | 1 |
| Pula Brilliant Blue RAWL | 0.05 | 0.05 | 0.1 | 0.1 | 0.5 | 0.5 |
| Albegal Set | 1.5 | | 1 | | 0.5 | |
| Ammonium Sulfate | | 0.2 | | 0.4 | | 0.5 |
| Acetic Acid | 1.5 | 1.5 | 3 | 3 | 4.5 | 4.5 |
| low Temperature Additive | | 0.3 | | 0.6 | | 0.8 |

Dyeing liquor ratio 1:30

**Fiber Tensile Property Test**

The tensile property of single cashmere fiber was tested using YG001N Electronic Single Fiber Strength Tester, and the fiber test length was 10mm; the tensile speed was 10mm/min. 300 fibers were tested for each result.

**Color Fastness Test**

Water washing and soaping washing color fastness of dyed cashmere were tested according to the GB/T3921-2008, heat fastness was tested according to the GB/T6512-1997, and fastness to perspiration was tested according to the GB/T3922-1995, and then the staining fastness rating was assessed by using staining gray card.

**Surface Morphology Test**

The surface morphology of cashmere fiber was observed using JSM-5800 scanning electronic microscope. The fibers were coated by gold, and then test was done.

## RESULTS AND DISCUSSION

**Tensile Properties**

The breaking strength of raw cashmere was 4.87cN, and the breaking elongation was 45.25%. The strength and elongation of dyed cashmere fibers are listed in *Table II.*

TABLE II. Tensile properties of dyed cashmeres.

| property | light color | | medium color | | dark color | |
|---|---|---|---|---|---|---|
| | Conventional | Low -temperature | Conventional | Low -temperature | Conventional | Low -temperature |
| breaking strength /cN | 3.90 | 4.54 | 3.76 | 4.38 | 3.58 | 4.18 |
| elongation/% | 38.2 | 45.0 | 37.1 | 43.2 | 35.0 | 40.9 |

*Table II* shows that the breaking strength and elongation of dyed cashmere fiber are lower than those of raw cashmere fiber. However, the breaking strength and elongation of fiber by low-temperature dyeing are higher than by conventional dyeing. So, the low temperature dyeing of cashmere can reduce the fiber damage.

## Color Fastness

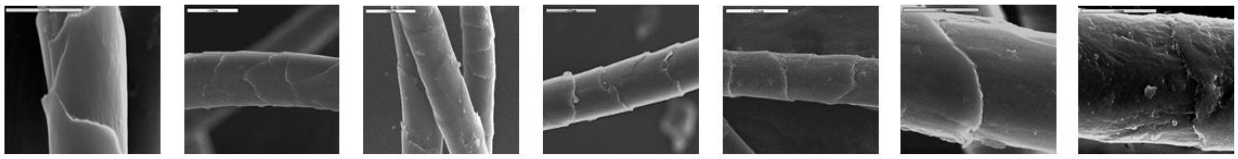
The color fastness of dyed cashmere fibers are shown in *Table III.* It can be seen that the color fastness of light-color and medium-color by low-temperature dyeing are the same as by high-temperature dyeing, however, the color fastness of dark-color by low-temperature dyeing is low.

TABLE III. Color fastness of dyed cashmere fibers.

| color | temperature | soaping | | watering | | | Perspiration | |
|---|---|---|---|---|---|---|---|---|
| | | Cotton staining | Wool staining | Cotton staining | Wool staining | Heat Fastness(180℃) | Cotton staining | Wool staining |
| light color | Conventional | 4-5 | 4-5 | 4-5 | 4-5 | 5 | 4-5 | 4 |
| | Low-temperature | 4-5 | 4-5 | 4-5 | 4-5 | 5 | 4 | 4 |
| medium color | Conventional | 4-5 | 4-5 | 4-5 | 4-5 | 5 | 4-5 | 4 |
| | Low-temperature | 4-5 | 4-5 | 4-5 | 4-5 | 5 | 4 | 4 |
| dark color | Conventional | 4 | 4 | 4 | 4 | 5 | 4-5 | 4 |
| | Low-temperature | 3-4 | 3-4 | 4 | 4 | 4 | 4 | 4 |

## Surface Morphology

The surface morphologies of raw cashmere fiber and dyed cashmere fiber are shown in *Figure 2. Figure 2* shows that the scale morphology of cashmere by low-temperature dyeing has less damage compared with by conventional dyeing. The scale morphology of dark color by conventional dyeing has serious damage. In order to keep scale morphology of fiber, the low-temperature dyeing technology should be used. For conventional dyeing, cashmere fibers first adsorb H+ in the acidic bath, fibers have positive charge. There are anions and acid radical ions in dyeing liquor, the dye stuff spreads on the fiber surface to replace the acid radical ions and enters the fibers. The carboxyl group and amino group of cashmere combine with hydrogen ions in dyeing liquor, which leads to the break of disulfide bonds in main chain, so that the surface of cashmere fiber damages seriously. During the process of low temperature dyeing, low temperature dyeing auxiliaries act on the surface scales of cashmere, and opens the disulfide bonds and some peptide bonds, which helps the dye stuff moving into the inside of fibers, the damage of scale is relatively less.



(a)raw cashmere fiber | (b)light color for low temperature dyeing. | (c)light color for high temperature dyeing. | (d)medium color for low temperature dyeing | (e)medium color for high temperature dyeing | (f)dark color for low temperature dyeing | (g)dark color for high temperature dyeing

FIGURE 2. Surface morphology of cashmere fiber.

## CONCLUSION

The breaking strength and elongation of dyed cashmere fiber by low-temperature dyeing are higher than by conventional dyeing, and scale morphology of fiber by low-temperature dyeing has less damage. The color fastness of dyed cashmere with light-color and medium-color by low-temperature dyeing are the same as by high-temperature dyeing. But the color fastness of dyed cashmere with dark color by low temperature dyeing is less than by high temperature dyeing.

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