Study on Dyeing Process of Bamboo Pulp Fiber Fabric with Pomegranate-peel Dye

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Abstract: The pomegranate-peel dye was extracted by boiling in this paper. Through orthogonal experiments, using dye fixation rate as an indicator, it has studied the best dyeing process of pomegranate-peel dye for dyeing bamboo pulp fibers with direct dyeing and same-bath mordant dyeing methods. The dyeing process parameters are optimized through orthogonal experiments as follows: (1) with direct dyeing method, when dyeing 30 minutes or 50 minutes, the optimal process parameters are dyeing concentration X, dyeing temperature 80℃, and dyeing PH value 8; when dyeing 70 minutes, the optimal process parameters are dyeing concentration 2/3X, dyeing temperature 80℃, and dyeing PH value 9. (2) with same-bath mordant dyeing method, when dyeing 30 minutes, the optimal process parameters are dyeing concentration X, dyeing temperature 80℃, and dyeing PH value 8; when dyeing 50 minutes, the optimal process parameters are dyeing concentration 2/3X, dyeing temperature 60℃, and dyeing PH value 7; when dyeing 70 minutes, the optimal process parameters are dyeing concentration X, dyeing temperature 60℃, and dyeing PH value 9. It is concluded that the bamboo pulp fiber dyed with pomegranate-peel dye has good dyeing performance, which meets the color fastness requirements of fabrics.

1. Introduction

As society develops, more and more people realize the importance of environmental protection, and the concept of green consumption prevails. In the field of textiles and apparel, consumers are increasingly interested in vegetable dyes. Since vegetable dyes are non-toxic, harmless, non-allergenic and carcinogenic to the skin, and have good biodegradability and environmental compatibility [1-2], they have good development prospects in high-end textile and apparel products.

Pomegranate-peel dye is a non-polluting and sustainable renewable natural dye, which has strong medicinal value. Scientists have also found that the effective ingredients have obvious antibacterial effects on various skin fungi through the antibacterial test with the extract of pomegranate peels [3]. Bamboo-pulp fiber is a new type of ecological and environmentally friendly regenerated cellulose fiber. Its fabric has excellent UV protection, antibacterial, good wearability and green environmental protection. It is known as “the most promising healthy fabric in the 21st century” [4-7]. In the field of bamboo-pulp fiber dyeing, domestic researchers have conducted a lot of research in recent years and accumulated some experience, but most of them are conventional chemical dyeing, and plant dyes are rarely involved.

The pomegranate-peel dye was extracted by boiling in this paper. Through orthogonal experiments, using dye fixation rate as an indicator, it has studied the best dyeing process of pomegranate-peel dyes for dyeing bamboo-pulp fibers with the direct dyeing and same-bath mordant dyeing methods, and the color fastness of bamboo-pulp fiber dyed with pomegranate-peel dye.
2. Experimental procedures

2.1. Experimental materials and equipment

Bamboo-pulp woven fabric (Fujian Hongyuan Group Co., Ltd.).

Drug: 0.1mol/L sodium hydroxide; L-histidine hydrochloride monohydrate; sodium dihydrogen phosphate dehydrate; 0.2mol/L copper sulfate; 0.6mol/L sodium hydroxide (the above are all analytically pure); Sodium chloride, dried pomegranate peel.

Instrument: WT2102T textile electronic balance; YG(B)631 color fastness to perspiration tester; SW-12A II color fastness to washing tester; Y(B)571-II color fastness to rubbing tester; Instron5565 universal strength tester; Thermostatic water bath; Thermometer; Timekeeper; pH test paper; Standard grey scale; Test tube; Beaker, etc.

2.2. Extraction of pomegranate-peel dye

According to the reference [8], the best extraction process of pomegranate-peel dye is boiling water. First, pound the dried pomegranate peels into powder, take 9 grams of pomegranate-peel powder in a beaker, add 100mL of distilled water, and heat them in a constant-temperature water-bath at 80℃ for 90 minutes; Second, filter the heated dyeing solution with gauze and filter paper funnel three times respectively in order to remove the residue of pomegranate peels, to obtain the pomegranate-peel dyeing solution used in this experiment and set its concentration as X; Finally, prepare three kinds of dyeing solutions with concentrations of X, 1/3X and 2/3X for the following experiments.

2.3. Dyeing Experiments

Select the methods of direct dyeing and the same-bath mordant dyeing (mordant, 0.2mol/L copper sulfate) to dye the bamboo-pulp fibers. Use L9 (3^4) orthogonal experiments to study the effects of dyeing temperature, time, PH value, and dye concentration on the dyeing performance of bamboo-pulp fiber fabrics[10].

2.3.1. The method of direct dyeing

Put 10×15 (cm) experimental fabric samples in 100ml pomegranate-peel dyeing solutions at different temperatures (40℃, 60℃, 80℃), concentrations (X, 2/3X, 1/3X) and PH value (7, 8, 9), and dye them for 30minutes, 50minutes or 70minutes. After dyeing, cool them down, wash them, and dry them [11, 12].

2.3.2. The method of the same-bath mordant dyeing

Put 10×15 (cm) experimental fabric samples in 100ml pomegranate-peel dyeing solutions added 8g 0.2mol/L copper sulfate as mordant at different temperatures (40℃, 60℃, 80℃), concentrations (X, 2/3X, 1/3X) and PH value (7, 8, 9), and dye them for 30minutes, 50minutes or 70minutes. After dyeing, cool them down, wash them, and dry them [11, 12].

2.4. Dyeing properties test

2.4.1. Fixation rate of dyeing

Using weighing method to calculate the fixation rate of the experimental fabrics, we can know the dyeing effects of the bamboo-pulp fiber fabrics with different dye time, dye temperature, dye PH value, and dye concentrations, so as to obtain the best dyeing process parameters.

2.4.2 Color fastness of dyeing

Rubbing fastness and perspiration fastness were tested respectively according to GB/T 3921-2008 “textile color fastness test the fastness to soaping”, GB/T 3920-2008 “textile color fastness test rubbing fastness” and GB/T 3922-2008 “textile color fastness test the color fastness to perspiration”.

3. Results and analysis

3.1. The results with the direct dyeing method
Table 1 shows the results of orthogonal experiments with direct dyeing method for 30 minutes. **Table 1.** Results of orthogonal experiment with the direct dyeing method for 30 minutes

| NO. | Dyeing temperature /°C | PH value | Dye concentration / g·mL⁻¹ | Fixation rate (%) |
|-----|------------------------|----------|-----------------------------|------------------|
| 1   | 40                     | 7        | X                           | 7.8              |
| 2   | 40                     | 8        | 2/3X                         | 8.3              |
| 3   | 40                     | 9        | 1/3X                         | 6.1              |
| 4   | 60                     | 8        | 1/3X                         | 7.1              |
| 5   | 60                     | 9        | X                            | 8.6              |
| 6   | 60                     | 7        | 2/3X                         | 6.3              |
| 7   | 80                     | 9        | 2/3X                         | 8.4              |
| 8   | 80                     | 7        | 1/3X                         | 6.8              |
| 9   | 80                     | 8        | X                            | 10.1             |
| K1  |                        |          |                              | 22.2             |
| K2  |                        |          |                              | 22               |
| K3  |                        |          |                              | 25.3             |
| R   |                        |          |                              | 3.3              |

As shown in Table 1, with direct dyeing method for 30 minutes, the fixation rate obtained in the ninth group of experiments is the highest, which dyeing process parameters are the concentration of dyeing solution X, the dyeing temperature 80 °C and the PH value of dyeing solution 8. From the magnitude of the extreme R value, we can know that the concentration of the dyeing solution has the greatest influence on the pomegranate-peel dyeing the bamboo-pulp fiber fabric with direct dyeing method, followed by the dyeing solution PH value, and finally the dyeing solution temperature. From this, it can be known that with the direct dyeing method, when the dyeing time is 30 minutes, the best process parameters of the pomegranate-peel dye on the bamboo-pulp fiber fabrics are: the dye solution concentration is X, the dyeing temperature is 80 °C, the dye solution PH value is 8.

Similarly, when the dyeing time is 50 minutes, the best process parameters of the pomegranate-peel dye on the bamboo-pulp fiber fabrics are: the dye solution concentration is X, the dyeing temperature is 80 °C, the dye solution PH value is 8; when the dyeing time is 70 minutes, the best process parameters of the pomegranate-peel dye on the bamboo-pulp fiber fabrics are: the dye solution concentration is 2/3X, the dyeing temperature is 80 °C, the dye solution PH value is 9.

According to the tests of rubbing fastness (dry rubbing and wet rubbing) and perspiration fastness (acid and alkali resistance), it is known that the pomegranate–peel dye has good color fastness when it dyes the bamboo-pulp fiber fabric with direct dyeing method. The color fastness to rubbing has reached the level of 3-4, and the color fastness to perspiration has reached the level of 3 or above, and with the increase of the dyeing time, the color fastness to rubbing and the color fastness to perspiration have also increased, satisfying the fabric color fastness standard; In addition, the color fastness of pomegranate-peel dye to alkali perspiration is worse than that of acid perspiration, because the pomegranate-peel dye is weakly acidic and easily reacts with alkaline substances.

### 3.2. The results with the same-bath mordant dyeing method

Table 2 shows the results of orthogonal experiment with the same-bath mordant dyeing method for 30 minutes. **Table 2.** Results of orthogonal experiment with the same-bath mordant dyeing method for 30 minutes
As shown in Table 2 with the same-bath mordant dyeing method for 30 minutes, the fixation rate obtained in the ninth group of experiments is the highest, which dyeing process parameters are the concentration of dyeing solution X, the dyeing temperature 80 ℃ and the PH value of dyeing solution 8.

From the magnitude of the extreme R value, it can be known that the concentration of the dyeing solution has the greatest influence on the pomegranate-peel dyeing the bamboo-pulp fiber fabric with the same-bath mordant dyeing method, followed by the dyeing solution PH value, and finally the dyeing solution temperature. From this, it can be known that with the same-bath mordant dyeing method, when the dyeing time is 30 minutes, the best process parameters of the pomegranate-peel dye on the bamboo-pulp fiber fabrics are: the dye solution concentration is X, the dyeing temperature is 80 ℃, the dye solution PH value is 8.

Similarly, when the dyeing time is 50 minutes, the best process parameters of the pomegranate-peel dye on the bamboo-pulp fiber fabrics are: the dye solution concentration is 2/3X, the dyeing temperature is 70 ℃, the dyeing solution PH value is 7; when the dyeing time is 70 minutes, the best process parameters of the pomegranate-peel dye on the bamboo-pulp fiber fabrics are: the dye solution concentration is X, the dyeing temperature is 60 ℃, the dye solution PH value is 9.

According to the tests of rubbing fastness (dry rubbing and wet rubbing) and perspiration fastness (acid and alkali resistance), it is known that the pomegranate –peel dye has better color fastness when it dyes the bamboo-pulp fiber fabric with the same-bath mordant dyeing method than with the direct dyeing method. The color fastness to rubbing has reached level 4 and above, and the color fastness to perspiration has reached level 3 and above, and with the increase of dyeing time, the color fastness to rubbing and perspiration have also increased, satisfying color fastness standards for fabrics. However, because the pomegranate-peel dye is weakly acidic and easily reacts with alkaline substances, the color fastness of the pomegranate-peel dye to alkali perspiration is poorer than that of the acid perspiration; The addition of copper sulfate mordant reduces the color fastness of the pomegranate -peel dye to alkali perspiration to a certain extent, but increases its color fastness to rubbing.

| O. N | Dyeing temperature / ℃ | PH value | Dye concentration / g·ml⁻¹ | Fixation rate (%) |
|------|------------------------|----------|-----------------------------|-----------------|
| 1    | 40                     | 7        | X                           | 9.6             |
| 2    | 40                     | 8        | 2/3X                         | 8.3             |
| 3    | 40                     | 9        | 1/3X                         | 6.0             |
| 4    | 60                     | 8        | 1/3X                         | 7.5             |
| 5    | 60                     | 9        | X                            | 6.6             |
| 6    | 60                     | 7        | 2/3X                         | 6.2             |
| 7    | 80                     | 9        | 2/3X                         | 6.9             |
| 8    | 80                     | 7        | 1/3X                         | 5.3             |
| 9    | 80                     | 8        | X                            | 11.4            |
| K1   | 23.9                   | 21.1     | 27.6                         |
| K2   | 20.3                   | 27.2     | 21.4                         |
| K3   | 23.6                   | 19.5     | 18.8                         |
| R    | 3.6                    | 6.1      | 8.8                          |
4. Conclusions
(1) With the direct dyeing method, when the dyeing time is 30 minutes, the best process parameters for the pomegranate-peel dye to dye the bamboo-pulp fiber fabric are: the dyeing solution concentration is X, the dyeing temperature is 80°C, and the dyeing solution PH value 8; when the dyeing time is 50 minutes, the best process parameters are: the concentration of the dyeing solution is X, the dyeing temperature is 80°C, and the pH value of the dyeing solution is 8; when the dyeing time is 70 minutes, the best process parameters are: the dyeing solution concentration is 2/3X, the dyeing temperature is 80°C, the PH value of the dyeing solution is 9.
(2) With the same-bath mordant dyeing method, when the dyeing time is 30 minutes, the best process parameters for the pomegranate-peel dye to dye the bamboo-pulp fiber fabric are: the dyeing solution concentration is X, the dyeing temperature is 80°C, the dye solution PH value is 8; when the dyeing time is 50 minutes, the best process parameters are: the dyeing solution concentration is 2/3X, the dyeing temperature is 60°C, the dyeing solution PH value is 7; when the dyeing time is 70 minutes, the best process parameters are: the dyeing solution concentration is X, the dyeing temperature is 60°C, the dyeing solution PH value is 9.
(3) The bamboo-pulp fiber fabrics dyed by pomegranate-peel dye have good color fastness, which meets the color fastness standard for fabrics.

Acknowledgements
At the end of this article, the author would like to thank Professor Yuan Xiaohong from the Fashion & Art Engineering Faculty of Minjiang University for guidance and assistance in the experimental design; I would also like to thank Chi Yuyao, a textile engineering student from the Fashion & Art Engineering Faculty of Minjiang University, for her assistance in the experiment.

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