Study on applying Chinese herbal medicine extract and essential oil to viscose fibers to achieve good results of antibacterial, anti-mosquitoes and anti-mites

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Abstract. The antibacterial, anti-mosquitoes and anti-mites functional viscose fiber was prepared by wet spinning method by adding aqueous solution of Radix Isatidis extract with antibacterial function, aqueous solution of Pelargonium roseum Ait extract with anti-mosquitoes function and Peppermint essential oil microcapsule with anti-mites function. Then its mechanical properties, antibacterial activity, anti-mosquitoes properties and anti-mites activity were measured. Compared with the mechanical properties of ordinary viscose fibers, its mechanical properties decreased slightly. When this kind of fiber was not washed, the inhibitory rates of the fiber against Staphylococcus aureus, Escherichia coli and Candida albicans were 95.5%, 99.12% and 79.35% respectively. After washing for 20 times, the inhibitory rates of the fiber were 94%, 91.53% and 77.43%. After washing for 40 times, the anti-mosquitoes rate of the fiber is still over 60%. After washing for 20 times, the anti-mites rate of the fiber was over 60%. Three functions of antibacterial, anti-mosquitoes and anti-mites exceeded national standards.

1. Introduction

China is the birthplace of herbal medicine. At present, there are about 12000 medicinal plants in China. This is not available in other countries. We have monopolistic advantages in traditional Chinese medicine resources. Compared with other chemical drugs, the biggest advantage of traditional Chinese medicine is green and natural, non-toxic side effects. Radix Isatidis can clear away heat and detoxify, and has better inhibition effect on Staphylococcus aureus, Escherichia coli and Candida albicans. Pelargonium roseum Ait is fragrant and contains a variety of alcohol substances, which can effectively repel mosquitoes. Peppermint can relieve fever and repel mites effectively[1]. In this paper, plant extract and essential oil of Chinese herbal medicine were added into viscose spinning solution to make it possess the function of antibacterial, anti-mosquitoes and anti-mites, and the research prospect is broad.

2. Experimental

2.1. Preparation before experiment

In the previous exploratory test, the properties of the blend film were tested in various aspects. It was found that the swelling properties of the blend film were better and the surface was smoother when the
Chinese herbal medicine extract was added to the viscose spinning solution in the form of aqueous solution. On the other hand, the volatility of the plant traditional Chinese medicine essential oil is strong, if directly added to the spinning solution, the effect is poor. So this paper will make the plant traditional Chinese medicine essential oil into microcapsules. Then the microcapsules were added to the spinning solution.

2.1.1. Preparation of solution. First, weigh a certain amount of Radix Isatidis extract and put it in the beaker. Then, these extract are formulated into 20% aqueous solution. That is to say, every 100ml distilled water is added 25g plant herbal extract. These solution are filtered by 300 mesh filters for 3 times. According to the same procedure, the aqueous solution of Pelargonium roseum Ait extract is prepared.

2.1.2. Preparation of microcapsules. In this paper, the ultrasonic wave method is used to prepare Peppermint essential oil microcapsules. The method is as follows. The weight of specially treated beta cyclodextrin is M1. Add these beta cyclodextrins to the right weight of deionized water and continue stirring. Place these mixture to mix them evenly at room temperature. The weight of Peppermint essential oil is M2(M1/M2(3.5/1)). Add these Peppermint essential oil to a moderate amount of absolute ethanol. Stir the mixture to make it disperse evenly. The mixture was mixed with a mixture of beta cyclodextrin. Adjust the heating temperature of ultrasonic to 60 degrees and ultrasonic vibration for 2 hours. The mixture was cooled for 24 hours at 4 degrees in the fridge. Remove it from the fridge 24 hours later and filter it out. Finally, these mixture was dried in low temperature and vacuum conditions.

2.2. Preparation of samples

The optimum dosage for preparing blend spinning solution is to add 3ml Radix Isatidis extract water solution, 3ml Pelargonium roseum Ait extract water solution and 2g Peppermint essential oil microcapsules to every 100ml spinning solution. These blend spinning solution was stirred with an electric mixer. Stirring makes the aqueous solution of Radix Isatidis extract, the aqueous solution of Pelargonium roseum Ait extract and Peppermint essential oil microcapsule disperse stably and evenly in viscose spinning solution. After static, filtering, defoaming and ripening, these blend spinning solution was ejected through the spinneret. It forms fibrous bundles in coagulation bath. After processing, these fiber bundles are made into 1.67dtex*38mm fibers. This is antibacterial, anti-mosquitoes, anti-mites functional viscose fiber.

2.3. properties testing

2.3.1. Mechanical properties testing. The prepared antibacterial, anti-mosquitoes, anti-mites functional viscose fiber and ordinary viscose fiber were washed with distilled water. They were put into the oven and kept at 60 degrees for 6 hours. Adjust humidity for 24 hours in standard environment (the temperature is 20 and the humidity is 65%). According to the operation method of electronic single fiber strength tester at constant speed and elongation, it is tested (instrument parameter setting: interval 10mm, stretching speed 10mm/min). Each group of fiber samples was tested 20 times. And all data were recorded. This is mechanical properties under dry condition. Then, part of the fiber is soaked with water. In the same way, the mechanical properties of fibers were tested under wet condition. The above test results should be averaged.

2.3.2. Antibacterial activity testing. In this paper, pure viscose fiber was used as a control. Staphylococcus aureus, Escherichia coli and Candida albicans were selected as experimental strains. According to GB/T 20944.3-2008 Textiles-Evaluation for antibacterial activity-Part 3: Shake flask Method, the antibacterial activity of antibacterial, anti-mosquitoes and anti-mites functional viscose fiber was tested [2,3]. The inhibitory rate can be calculated according to formula (1).
Where \( Y \) is the inhibitory rate of the sample; \( W_t \) is the average of three viable bacteria in flasks of three contrasting samples after shocked for 18 hours; \( Q_t \) is the average value of viable bacteria in flasks of three experimental samples after shocked for 18 hours.

### 2.3.3. Anti-mosquitoes properties testing.

As shown in Figure 1, the antibacterial, anti-mosquitoes, anti-mites functional viscose fiber and ordinary viscose fiber are placed in cavity A and cavity C respectively. 50 female Aedes mosquitoes were put into cavity B. Then the partitions between A and B, B and C were removed. We need to observe the number of mosquitoes in cavity A and cavity C[4,5]. The anti-mosquitoes rate can be calculated according to formula (2).

\[
Q = \frac{N_C - N_A}{N_C + N_A} \times 100\%
\]  

(2)

Where \( Q \) is the anti-mosquitoes rate; \( N_A \) is the number of female Aedes mosquitoes in cavity A after anti-mosquitoes test; \( N_C \) is the number of female Aedes mosquitoes in cavity C after anti-mosquitoes test.

![Figure 1. Anti-mosquitoes tester](image)

### 2.3.4. Anti-mites activity testing.

According to GB/T 24253-2009 Textiles-Evaluation for anti-mites activity, anti-mites activity of antibacterial, anti-mosquitoes, anti-mites functional viscose fiber was tested[6,7]. The anti-mites rate can be calculated according to formula (3).

\[
M = \frac{B-T}{B} \times 100\%
\]  

(3)

Where \( M \) is the anti-mites rate; \( B \) is the average value of the live mites on three contrasting samples; \( T \) is the average value of the live mites on three experimental samples.

### 3. Results and discussion

#### 3.1. Mechanical properties

The test results of mechanical properties of antibacterial, anti-mosquitoes, anti-mites functional viscose fibers and ordinary viscose fibers are shown in Table 1.
Table 1. Basic mechanical properties of pure viscose fiber and functional viscose fiber

| Fiber samples            | Breaking tenacity (cN/dtex) | Elongation at break (%) |
|--------------------------|-----------------------------|-------------------------|
|                          | Dry state                   | Hygrometric state       | Dry state | Hygrometric state |
| Common viscose fiber     | 2.32                        | 1.62                    | 17.45     | 25.28             |
| Functional viscose fiber | 2.10                        | 1.48                    | 18.32     | 26.76             |

As can be seen from table 1, whether in dry or wet condition, the breaking strength of antibacterial, anti-mosquitoes, anti-mites functional viscose fiber is lower than that of ordinary viscose fiber. But the elongation at break increased. This is because the aggregation structure of functional viscose fibers is changed and the crystallinity is slightly decreased after adding plant extract solution and essential oil microcapsules to the viscose spinning solution. The excessive number of functional agent molecules between cellulose macromolecules hinders its hydrogen bonding with multiple cellulose molecules, which leads to the reduction of fracture strength. But the elongation is increased, because the cellulose molecules slip intensified.

3.2. Antibacterial activity

The antibacterial activity testing results of antibacterial, anti-mosquitoes and anti-mites functional viscose fiber are shown in Table 2.

Table 2. Antibacterial activity of functional viscose fiber

| Functional viscose fiber | Staphylococcus aureus ATCC 6538 (%) | Escherichia coli ATCC 25922 (%) | Candida albicans ATCC 10231 (%) |
|--------------------------|-------------------------------------|----------------------------------|---------------------------------|
| Bacteriostatic rate without washing (%) | 95.5                                | 99.12                            | 79.35                           |
| The bacteriostatic rate after washing for 10 times (%) | 94.56                               | 98.71                            | 78.26                           |
| The bacteriostatic rate after washing for 20 times (%) | 94.00                               | 91.53                            | 77.43                           |

As can be seen from Table 2, the antibacterial rate of antibacterial, anti-mosquitoes, anti-mites functional viscose fiber was more than 90% against Staphylococcus aureus and Escherichia coli. The bacteriostatic rate of Candida albicans was over 70%. It can be seen that it has strong antibacterial effect. This is because all three Chinese herbal medicines added have certain antibacterial activity. After washing for 20 times, the bacteriostatic rate decreased very little. This shows that it has strong
washing resistance. This is because the internal and external surfaces of the fibers are distributed with Chinese herbal medicine.

3.3. Anti-mosquitoes properties

The anti-mosquitoes effect of antibacterial, anti-mosquitoes, anti-mites functional viscose fiber is shown in Figure 2.

![Figure 2. Anti-mosquitoes rate varies with washing times](image)

From the figure 2, it can be seen that the anti-mosquitoes rate of antibacterial, anti-mosquitoes, anti-mites functional viscose fiber will decrease with the increase of washing times, but the decrease is not obvious. After washing for 40 times, the anti-mosquitoes rate is still above 60%, exceeding the relevant national standards. It also shows that the fiber has good washing resistance.

3.4. Anti-mites activity

The anti-mites activity of antibacterial, anti-mosquitoes and anti-mites functional viscose fiber is shown in Table 3.

| samples               | Washing times | Culture time | The number of mites in contrast group | The number of mites in experimental group | Anti-mites rate (%) |
|-----------------------|---------------|--------------|--------------------------------------|------------------------------------------|---------------------|
| Functional viscose fiber | 0 times       | 24h          | 104                                  | 25                                       | 76.53               |
| Functional viscose fiber | 20 times     | 24h          | 105                                  | 38                                       | 64.65               |

As can be seen from Table 3, the anti-mites rates of antibacterial, anti-mosquitoes and anti-mites functional viscose fiber were more than 60% after washing for 0 and 20 times. According to the national standard, this fiber has anti-mites effect. This is because Peppermint oil microcapsules added to functional fibers have a strong anti-mites effect.
4. conclusion

The molecular structure of viscose fibers was not changed by adding plant traditional Chinese medicine extract aqueous solution and plant traditional Chinese medicine essential oil microcapsule to viscose spinning solution. The mechanical properties decreased slightly, but did not affect their wearability. The antibacterial, anti-mosquitoes and anti-mites rates of functional viscose fiber were over 80%, 60% and 60% respectively after washing for 20 times. All of these meet the requirements of national standards. This study shows that it is feasible to make viscose fibers with various new functions by adding natural plant traditional Chinese medicine extract and essential oil. These studies provide a broad prospect for the development of functional fibers and garments.

References

[1] Chan B, Yu J, Li M. Chinese Herbal Medicine: An Old Tradition[J]. Alive Canadas Natural Health & Wellness Magazine, 1996(5977):237.
[2] Xiao Y N, Zheng H M. Preparation and Characterization of the Polyacrylonitrile Antibacterial Fiber Containing Multi-functional Groups[J]. Journal of Functional Polymers, 2001.
[3] Liu W S. DEVELOPMENT OF ANTIBACTERIAL FIBER AND APPLICATION OF ANTIBACTERIAL TEXTILES[J]. Chemical Fiber & Textile Technology, 2011.
[4] Bai L, Academy C T. Spinning Process Research on Anti-Mosquito Polyester Fibers[J]. Synthetic Fiber in China, 2016.
[5] Textile Anti-mosquito Finishing and Test Standard[J]. China Fiber Inspection, 2010.
[6] Ma Z, Jin H. Advance of Research on Anti-mite Fibers and Textiles[J]. Petrochemical Technology in Jinshan, 2002.
[7] Jiao W U, Wan X Y, Tian P, et al. Chinese Medicine Anti-Microbial & Anti-Mite Viscose Fibers Prepared by Microcapsule Technology and its Properties[J]. Synthetic Fiber in China, 2017.