A New Method for Conservation of Ancient Colored Drawing on Hemp Textiles

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Abstract

As a kind of textile, hemp artifact is a valuable cultural heritage. Suffering from several degradation factors in the preservation of cultural relics, some ancient hemp colored-paintings have been damaged, further affected their ornamental values. Therefore, it is urged to take the suitable conservation measures to protect the precious hemp artifacts for the historical culture succession. In this paper, an examination and analysis of the hemp colored paintings were the first step to propose an appropriate conservation treatment. Ultra-depth-of-field microscope was used to identify the kinds of fiber, and scanning electron microscope (SEM) was utilized to observe their condition and surface morphology. The element distribution and composition were identified by SEM, energy disperse spectroscopy (EDS) and X-ray fluorescence spectroscopy (XRF). Gas chromatography-mass spectrometer (GC-MS) was applied to identify the kinds of binding media and amino acid composition. Moreover, novel reinforcement materials and technology were proposed with the principle of compatibility and feasibility. The properties of tensile strength, aging resistance and chromatic aberration were tested before and after dry heat aging, wet heat aging and UV light aging. After systematic examination and evaluation of the hemp colored paintings and reinforcement materials, the optimal conservation treatment was finally established, and the Chinese hemp painting as an example has been protected successfully. This paper provides new methods and ideas for the restoration and protection of the linen cultural relics, which would promote the progress of protecting valuable cultural heritages.

1. Introduction

Textiles in all forms are an essential part of human civilization [1], hemp fibers as one textile were used for weaving uniforms, weaving hemp ropes, drawing hemp paintings, and also as raw materials for making scriptures. China has a history of more than five thousand years, Liao and Jin era is an important period in ancient China, a lot of hemp colored paintings about Buddhist culture and history art work were left. They would provide an important reference to understand the historical prosperity, decline and Buddhist culture in the Chinese Liao and Jin era. For example, as shown in Fig. 1, there is a hemp colored drawing: Bodhisattva banner-hangings, the banner hand on the left and right of the banner body and the banner foot below the banner have been lost, both have height of 160 cm and width of 30 cm. The body of this pair of banner-hanging Bodhisattvas is almost entirely the image of Bodhisattvas in early Indian Buddhism, and it is a rare Buddha painting made on hemp cloth. The paintings show the light and dark expression methods, and the painting style has obvious characteristics, which integrate many artistic characteristics of India, Greece and the Western Regions of China. This pair of the hemp-colored drawing Bodhisattva banner-hangings is undoubtedly the painting of the Western Regions of China during the Northern and Southern Dynasties.

Archeological hemps in museums are exposed to many challenges such as oscillate relative humidity (RH), changing temperature, effect of light, effect of air pollution, non-standard storage and display methods. The hemp fiber is easy to react with water, carbon dioxide and sulfur dioxide in the air, which leads to the deterioration of the fiber. In addition, the deposition of a large number of dust and microorganisms on the surface accelerates the considerable loss of tensile strength and pliability. As a result, these negative factors affect the ornamental values of hemp fabric. To solve these problems, the optimal conservation measures should be taken to rid the inappropriate fragment sand improve the properties of textile objects for the long-term stability [2],thereby to slow down the rate of the further deterioration of hemp artifacts as much as possible [3].There is no universal protective measure for all textiles, normal conservation measures include cleaning dust and stains, pre-reinforcement of colored painting, fixing separate parts, supporting weak and damaged areas with new fabrics using stitching techniques, and so on. Previous reports mainly focus on the degradation of historical textiles [4-7], the preservation environment of archaeological textiles [8, 9], identification of dyestuffs in historical textiles [10-13], examination of cellulose textile fibers [14], fungal contamination of textile objects [15], and textile cleaning [16].

Against such a background, the novel protective materials and conservation measures should be investigated to protect the precious hemp artifacts for the historical culture succession. In this article, how to select protective material is the first step for the restoration measures, at least, it should possess an appropriate structure, weight and fiber to provide support to the textile [17]. Thereby, the type of fibers and fillers, proteinaceous binding medium, and extent of damage are studied through different ways of investigation. Then, based on the principle of compatibility and reversibility, the new reinforced materials and techniques are proposed. Finally, the conservation process of the Chinese hemp paintings is developed, including flatten and preliminary splicing, pre-reinforcement of colored painting, dust and stain cleaning, fine splicing, reinforcement of the hemp net and filling holes. These techniques would enrich conservation scientist information about the conditions of preservation and physic chemical properties of materials [18]. Overall, our research aim is to rid the inappropriate fragments and improve the properties of textile objects for the long-term stability, thereby to slow down the rate of the further deterioration of hemp artifacts as much as possible.

2. Experimental

A certain museum has collected the hemp colored paintings of Chinese Liao and Jin era, and the samples are taken from the fragments of the rotten hemp colored paintings. The reinforced hemp nets were prepared as follow: the same kind of fiber compatible reinforcement materials was selected. The hemp net with a mesh of 2 mm × 2 mm is woven by the hemp wire with a diameter of about 75 μm. Then the 5% mass fraction of the PVA-217 aqueous solution was prepared as the adhesive, and a spray gun was used to evenly spray the adhesive on the hemp net. The distance between the gun head and the cotton net is 3 cm, the spray pressure of the spray gun is 0.5 MPa~0.8 MPa, and the coating thickness of the adhesive is 15~20 μm. Finally, the sprayed hemp net was dried naturally, and the hemp net was cut out from the weaving frame to get the reinforcing hemp net.

2.1 Aging process of reinforced hemp net

Three aging methods were employed to complete the aging process of reinforced hemp net, and three parallel experiments were carried out for each group of aging methods. Each sample has been respectively aged for 3 days, 5 days, and 7 days. One aging method is dry heat aging, the prepared hemp net and PVA film were put in a blast drying aging box at 105 °C. The second aging method is wet heat aging, the prepared hemp net and PVA film were put in a constant damp heat aging test box at a temperature of 80 °C and a relative humidity of 65%. The third aging method is ultraviolet light aging, an ultraviolet weather resistant test box was applied to age the hemp net and PVA film, the temperature of the aging box is set at 25 °C, the power of the ultraviolet lamp is 60 W, and the vertical distance between the sample and the ultraviolet lamp is 5 cm.

2.2 Characterization of material

2.2.1 Characterization of hemp

Preparation of Herzberg coloring agent and samples was reported [19, 20]. The KH-7700 ultra-depth-of-field microscope was used to observe the fiber morphology and dyeing state, and take the fiber pictures for comparison with the standard fiber atlas. The SU3500 tungsten filament scanning electron microscope (SEM) was utilized to characterize the hemp painting, spray the gold 80s on the sample surface with an ion sputtering instrument (30 mA), observe and analyze the sample surface under an acceleration voltage of 5 kV. Meanwhile, the SEM was applied to perform the X-ray energy spectrum analysis on the sample under the condition of an acceleration voltage of 15 kV, and make a preliminary guess on the filler of the hemp painting based on the elemental analysis results. EDX-7000 energy type X-ray fluorescence spectroscopy (XRF) was used to test the element composition of the hemp painting surface with test conditions as follow: Rh target, air atmosphere, tube voltage with Na~Sc, 15 KeV and Al~U, 50 KeV, the X-ray spot diameter of the sample is 1mm. Gas chromatography-mass spectrometer (GC-MS) was adopted to analyze the rubber in the hemp painting, 6 mol/L hydrochloric acid solution helped the hydrolysis of the protein in the rubber compound [21], and then MTBSTFA reagent was employed to derivatize the hydrolysate. The GC-MS analysis started after the derivatization is completed. The test conditions are as follow: helium as carrier gas, the sample inlet temperature is 280 °C, the flow rate is 1.5mL/min, the initial temperature is set at 100 °C, and then the temperature is increased to 280 °C at a rate of 6 °C/min, and it is maintained until all the sample flows out [22].

2.2.2 Durability characterization of these reinforcement materials

The QT-1136 universal material testing machine was adopted to test the tensile strength of the hemp net before and after aging for 5 days. The samples were cut into a long strip of about 15mm×5mm, then a universal material testing machine was used to measure the load when the hemp net is broken, and each sample was measured 10 times to get the average value of the load. The tensile strength is calculated according to the formula: $S=F/L_w$, where F is the load at break and Lw is the width of the sample. The X-RiteVS-450 spectrophotometer was applied to test the chromatic aberration ΔE^* of the reinforcement materials before and after aging for 3 days, 5 days, and 7 days, and each sample was measured 5 times to get the average value. The four layers of hemp net were superimposed to perform the test. The larger the value of ΔE^* is, the greater the color change of the sample is.

2.3 Restoration process

The Chinese Liao and Jin era dates back more than a thousand years, the colored paintings of hemp fabrics buried underground for so many years have been severely damaged, which seriously affected their viewing and exhibition in museums. Therefore, it is necessary to conduct the restoration treatment of the colored paintings of the damaged hemp fabrics, such as preliminary splicing, dust and stain cleaning, colored painting pigment pre-reinforcement, fine splicing, restoration of fabric textures, back reinforced hemp net, and restoration of defects with hemp net as the skeleton, to improve the mechanical strength of hemp fabrics. For this damaged hemp sample in the article, the restoration procedure was described as follows: flatten, pre-reinforcement of colored painting, dust and stain cleaning, fine splicing, reinforcement of the hemp net and filling holes.

3. Results And Discussion

3.1 Fiber analysis of hemp samples

As shown in Fig. 2, the fiber of sample one is relatively thick, one part of the fiber is shaped like a circular tube, another part of the fiber is shaped like a flat long ribbon, and the part of its surface has clear longitudinal stripes, thereby it can be inferred that the fiber material of sample one is ramie [23]. The fiber of sample two is relatively thin, and there are obvious horizontal knots on the fiber wall. When reacted with the fiber reagent, the sample two shows a wine-red color, which indicates its composition is 100% hemp fiber [24]. The identification of hemp painting morphology and fiber type would provide an effective basis to achieve the good compatibility of the reinforcement material during the restoration process.

3.2 Filler analysis of hemp fiber

The SEM morphology of sample one (Fig. 3a) shows that the fiber surface is relatively smooth, the X-ray fluorescence analysis result of sample one (Fig. 3b) shows that the content of Ca, Fe, and Si is very high, and the content of K, Ba, and S is relatively high. While the fiber surface of sample two (Fig. 3c) is covered with fine particles, and it may be that the surface has been filled or glued to improve the performance of the hemp painting. The X-ray fluorescence analysis result of sample two (Fig. 3d) shows that the content of Ca and Mn is very high, and the content of K, Si, Cl, and S is relatively high. Combined with the energy spectrum analysis results in Tables 1 and 2, it can be known that sample one contains more Ca, Fe, Si, K, and S elements, except C and O elements. The sample two contains more Ca, Mn, Si, K elements, and there is also N element, which may be introduced during the sizing treatment process. The hemp plants could be soaked or scoured with alkaline straw ash solution before weaving, and then starching the hemp cloth with paste-like talcum powder, kaolin, etc. To increase the strength of the hemp fabrics and make the appearance smooth [25], it is speculated that the hemp painting filler may contain talc, gypsum, kaolin, calcium oxide and so on.

Table 1
The X-ray fluorescence element analysis of sample one.

Elements	Ca	Si	Fe	K	Ba	S	Ti	Cr	Zn	Cu
Content/%	29.75	26.45	20.10	7.44	7.30	4.22	2.70	1.56	0.36	0.12

Table 2
The X-ray fluorescence element analysis of sample two.

Elements	Mn	Ca	Cl	K	Si	S	Ti	Cu
Content/%	41.94	24.19	14.21	13.56	4.20	1.42	0.36	0.12

3.3 Identification of hemp sizing material

From the GC-MS analysis diagram of both samples (Figs. 4 and 5), the amino acid composition of them is listed in Table 3, it can be seen that both samples contain Hyp (hydroxyproline), which is a characteristic amino acid of animal glue. The high content of Gly (glycine) is also one of the characteristics of animal glue [26], the content of Gly in sample two is 20.5%, which indicates that animal glue was used in the preparation of sample two. As shown in Fig. 6, it can be seen that the amino acid composition of both samples fell near the animal gluein the scatter diagram of ratio factor analysis. Combined with its amino acid composition characteristics, it is judged that their sizing materials may use the animal glue.

Table 3
Amino acid composition ratio (%) in the sample sizing material.

Sample	Ala	Gly	Val	Leu	Ile	Ser	Pro	Phe	Asp	Glu	Hyp
One	5.8	7.3	4.6	6.4	3.7	22.0	2.4	4.2	6.6	21.1	15.8
Two	11.3	20.5	4.7	6.9	4.1	20.2	10.1	3.1	5.5	9.1	4.6
Note: Asp, Ser, Glu, Pro, Gly, Ala, Val, Ile, Leu, Phe, Hyp in the table are respectively the abbreviations of aspartic acid, serine, glutamic acid, proline, glycine, alanine, valine, isoleucine, leucine, phenylalanine and hydroxyproline.											

3.4 Evaluation of hemp net before and after aging

As shown in Table 4, the retention rate of tensile strength of the hemp net after dry heat aging for 5 days and wet heat aging for 5 days is above 80%, and the retention rate of tensile strength after UV light aging for 5 days is above 90%, these aging results show that the hemp net possesses better durability.

Table 4
The tensile strength of hemp net before and after 5 days aging.

Aging methods	Without aging	Dry heat aging	Wet heat aging	UV light aging
Tensile strength /(kN/m)	1.30	1.05	1.08	1.20
Retention rate/%	100	80.67	82.52	91.95
Note: The data in the table is the average of 10 times of parallel tests.				

As shown in Fig. 7, it can be seen that the wet heat aging and ultraviolet light aging have less effect on the color of the reinforcement materials, while the dry heat aging makes more obvious color changes of the PVA film and hemp net. Thereby, it is speculated that the discoloration of the hemp net is caused by the color change of the PVA after aging. The discoloration of the PVA film is caused by the thermal oxidation reaction of the PVA in the dry heat aging box at 105 °C, and some of the hydroxyl groups are oxidized to carbonyl groups, and the reaction mechanism is shown in Fig. 8.

With the increasing aging time, the carbonyl content becomes high, and the color of the PVA film gradually changes from colorless to light yellow, and finally turns to yellow. Meanwhile, the PVA film weakens the toughness, becomes brittle and hard. Therefore, it is necessary to further improve the chromatic aberration changes before and after dry heat aging of the reinforcement material, before it can be applied to the reinforcement and restoration of cultural relics.

3.5 Restoration effect and process

As shown in Fig. 9(a), this original hemp painting was decayed, rotted, and broken before it was reinforced and restored. In order to preserve the original appearance of the cultural relics, some broken holes, breakages, and breaks could not be woven and restored. For later viewing and long-term preservation of cultural relics, the back of the hemp painting was strengthened by hemp net, and hemp net was employed as the skeleton to restore the broken holes and the broken parts by weaving, the restoration effect is good (Fig. 9b). The reinforcement technology of the hemp painting in this paper could provide an important reference for the restoration of decayed, damaged and rotten hemp fabrics. As shown in Fig. 10, the detailed restoration process is listed in the following:

(a) Flatten and preliminary splicing: we open the hemp colored painting on the table, and use tweezers to arrange the damaged fibers on the edge one by one.

(b) Pre-reinforcement of colored painting: as the cultural relics would inevitably come into contact with water during the restoration process, in order to prevent the pigment particles from falling off and diminishing, we can perform the pre-reinforcement with 8% aqueous fluorine ethanol and water blend solution before restoration. The cotton balls of uniform length, size, and thickness are treated as the absorbent cotton. The absorbent cotton is dipped into an appropriate amount of pre-reinforcer, and then it was applied evenly on the colored painting, and we let the colored painting dry naturally.

(c) Dust and stain cleaning: we add ultra-pure water into the ultra-fine atomization sprayer, and spray slowly on the hemp fabric. With the spray, the ultra-pure water flows out of the backing paper until the liquid flowing out is relatively clean. Then we roll it out with a rolled towel to make the cultural relics flat on the tabletop.

(d) Fine splicing: we splice the scattered and deformed fibers completely in accordance with the original textile warp and weft patterns of the hemp fabrics.

(e) Reinforcement of the hemp net: we cover the prepared hemp net on the back of the cultural relic and roll it flat with a wet towel, during this process, polyvinyl alcohol will be dissolved in water and it is sticky, during the dissolution process, it will be adhered and support to the back of the cultural relic, and we let it dry at room temperature.

(f) Filling holes: there are more or less broken holes in the cultural relics of different degrees, according to the texture of the fibers on the cultural relics; the broken holes are filled with twine of the same material and color.

4. Conclusion

The hemp colored painting reflects the life style and cultural characteristics of the people at that time, and there is a great significance for the study of ancient textile technology and the cultivation of fiber crops. This article takes one hemp painting of Chinese Liao and Jin era as an example. Through the analysis and detection of the composition of the hemp painting, the performance evaluation of the reinforcement materials before and after aging, and the implementation of the restoration process, the Chinese hemp painting has been protected successfully.

After dyeing fiber of the hemp painting with the Herzberg dye, the ultra-depth-of-field microscope observation results show that the main fiber raw materials of the hemp painting are ramie and hemp. The X-ray fluorescence spectroscopy and energy spectrum analysis reveal that the hemp painting mainly contains the compounds involving calcium, potassium, silicon, sulfur and so on, the specific substances need to be further studied. The amino acid composition characteristics indicate that the sizing materials of the hemp paintings contain the animal glue. In addition, the reinforcement materials were subjected to three kinds of artificial accelerated aging: dry heat, wet heat, and ultraviolet light. Through the characterizations of the tensile strength and chromatic aberration, the results indicate that the hemp net with same fiber possesses better durability. Finally, the actual restoration process includes: flatten and preliminary splicing, pre-reinforcement of colored painting, dust and stain cleaning, fine splicing, reinforcement of the hemp net and filling holes. Meanwhile, the restoration effect is good. Our results show a great significance for the fiber identification and reinforcement protection of ancient hemp cultural relics.

5. Abbreviations

SEM: Scanning electron microscope; EDS: Energy disperse spectroscopy; RH: Relative humidity; XRF: X-ray fluorescence spectroscopy; GC-MS: Gas chromatography-mass spectrometer; Asp: Aspartic acid; Ser: Serine; Glu: Glutamic acid; Pro: Proline; Gly: Glycine; Ala: Alanine; Val: Valine; Ile: Isoleucine; Leu: Leucine; Phe: Phenylalanine; Hyp: Hydroxyproline.

6. Declarations

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Authors' contributions

JL and YL provided support and guidance for this study. JL performed the restoration process of hemp colored drawing, and was a major contributor in writing the manuscript. HX and DH carried out literature and examination. XC and JC assisted in sample testing and data analysis. ZJ was involved in the initial concept of the examination. All authors read and approved the final manuscript.

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Availability of data and materials

All data are available on request.

Competing interests

The authors declare that they have no competing interests.

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Figures

Figure 1

The photo of an ancient linen fabric.

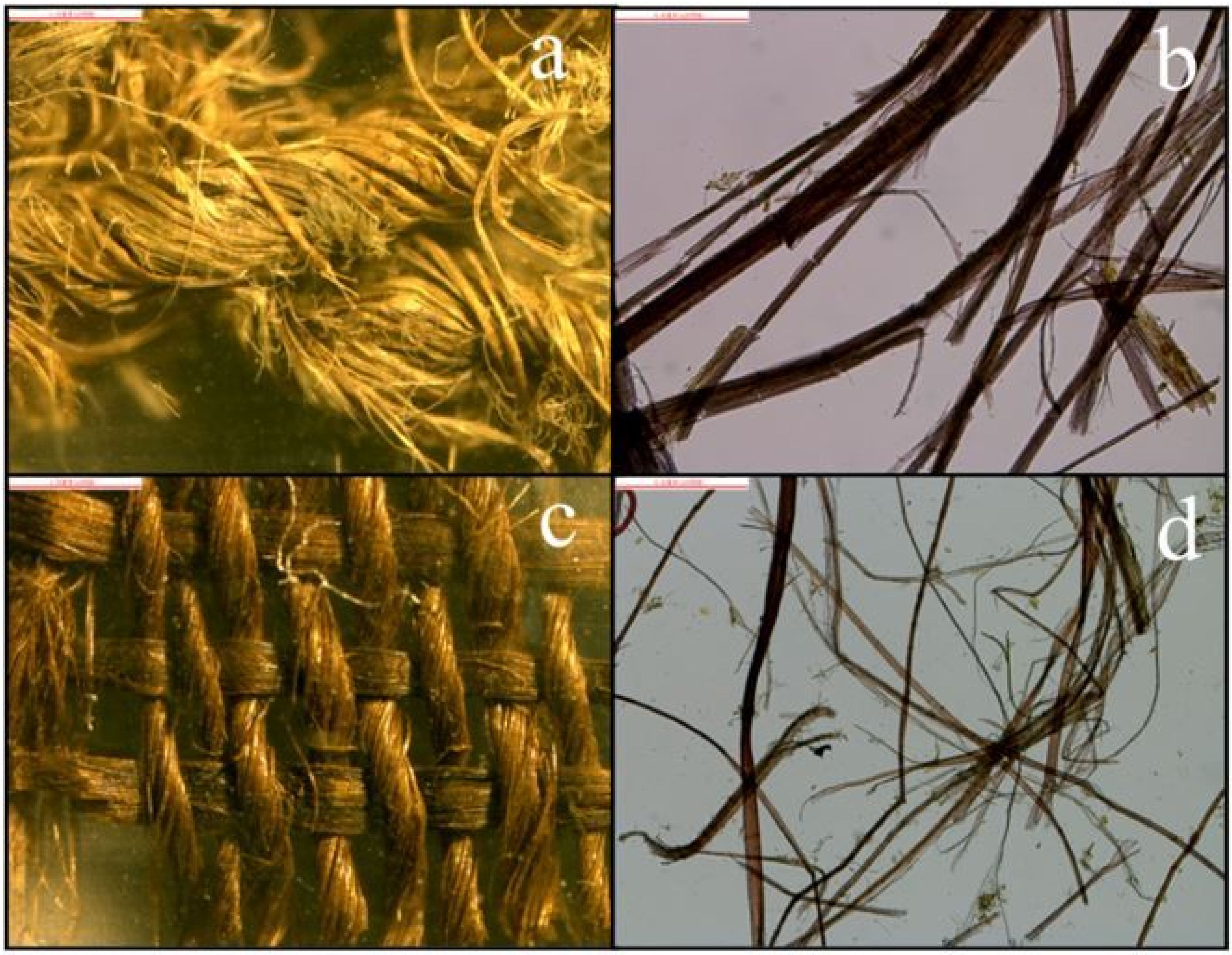

Figure 2

The morphologies of sample one before (a) and after dyeing (b), sample two before (c) and after dyeing (d).

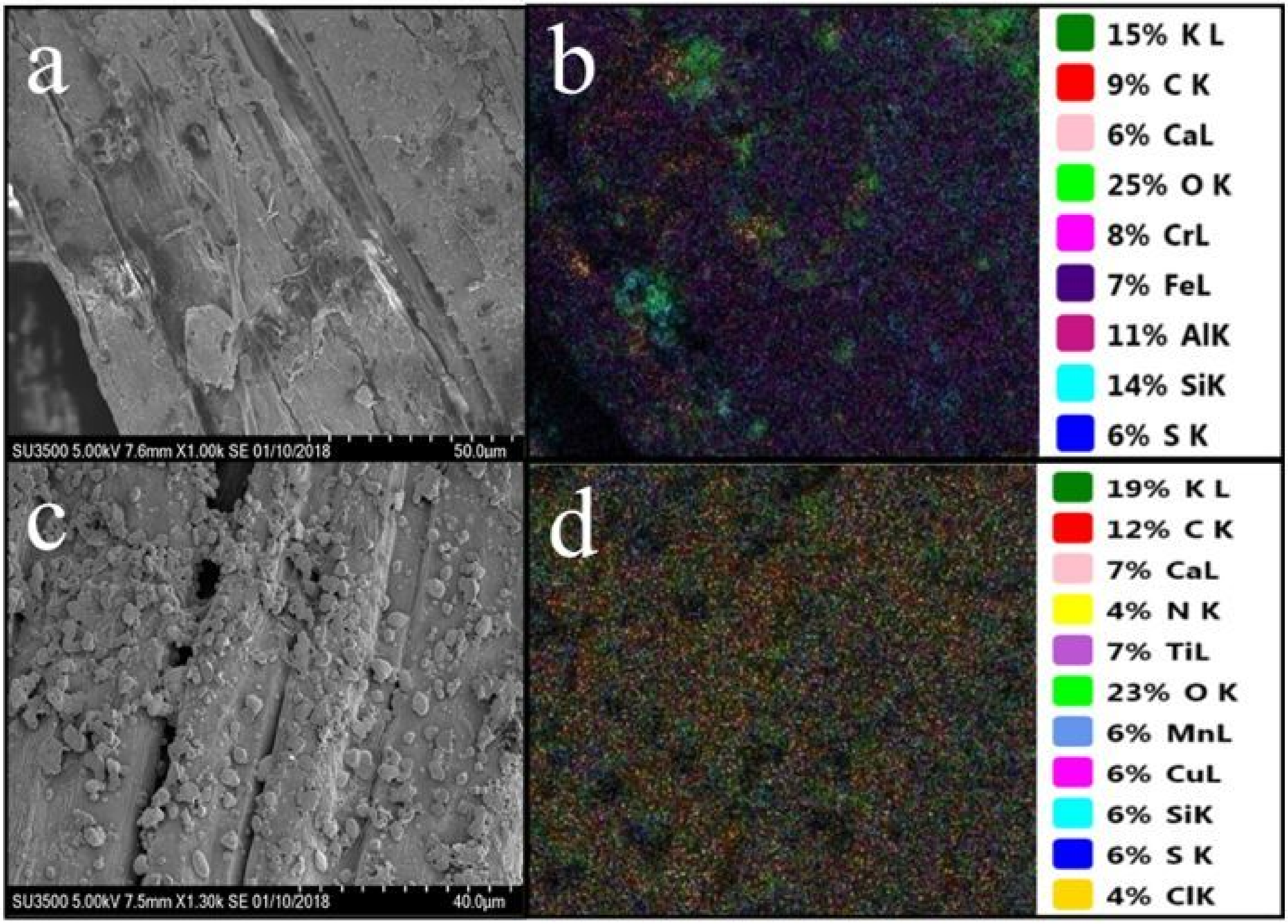

Figure 3

The SEM morphology (a) and the surface scan element distribution diagram (b) of sample one, the SEM morphology (c) and the surface scan element distribution diagram (d) of sample two.

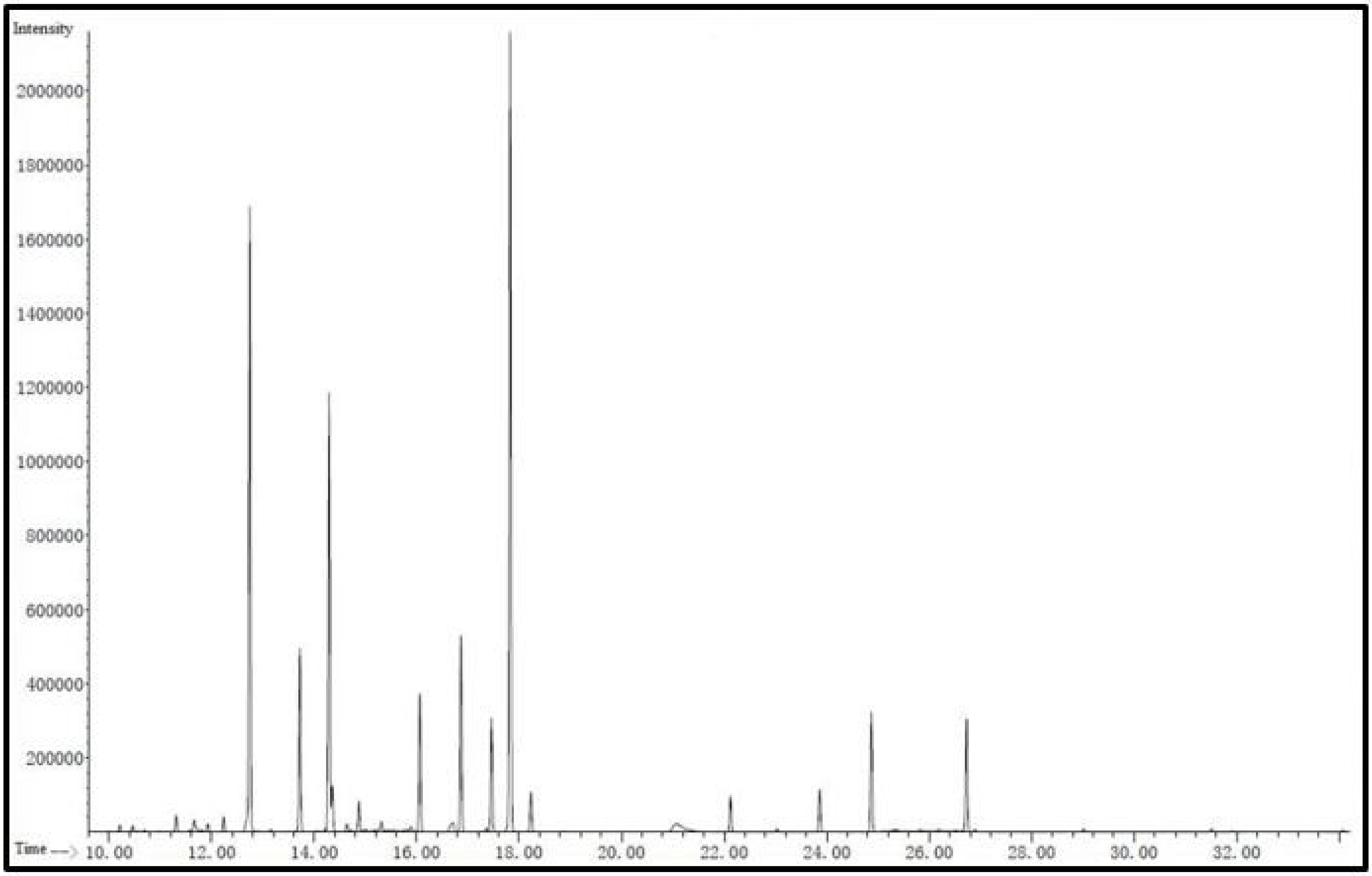

Figure 4

Gas chromatogram of sample one.

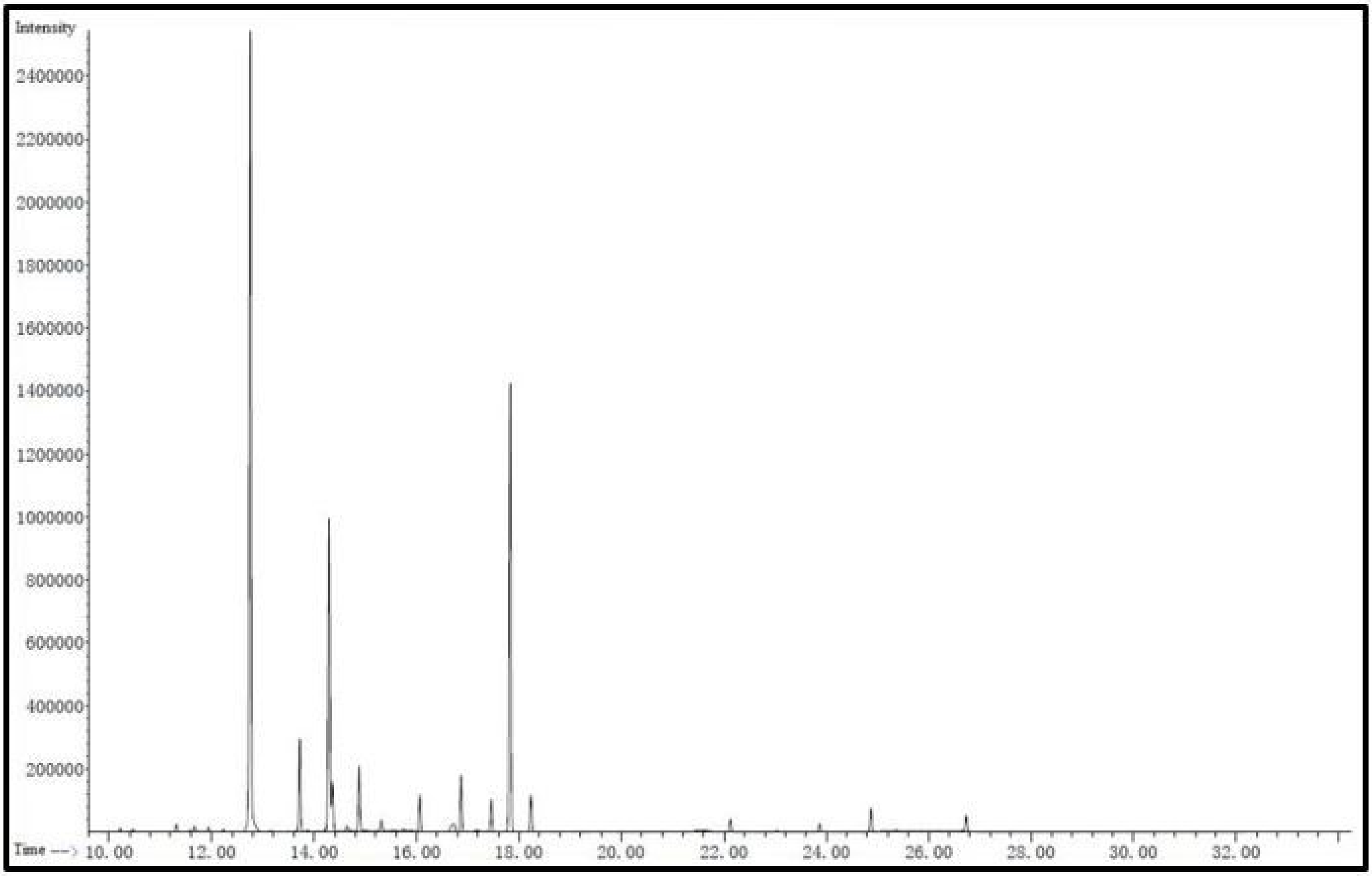

Figure 5

Gas chromatogram of sample two.

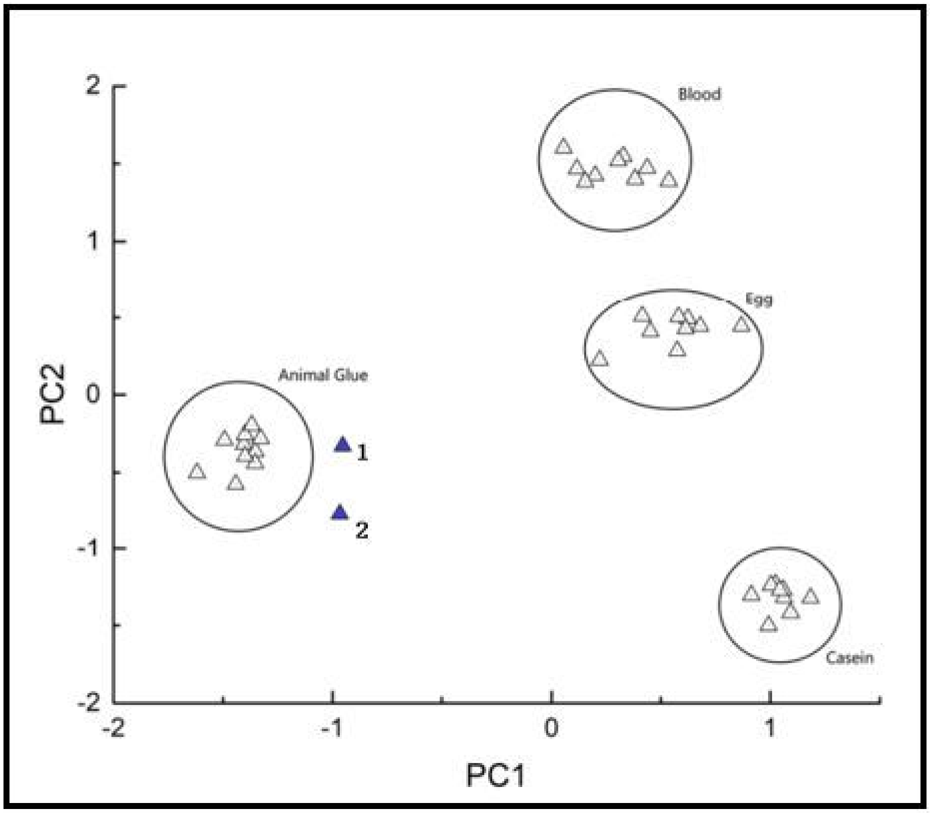

Figure 6

Scatter diagram of ratio factor analysis of amino acid composition in samples one and two.

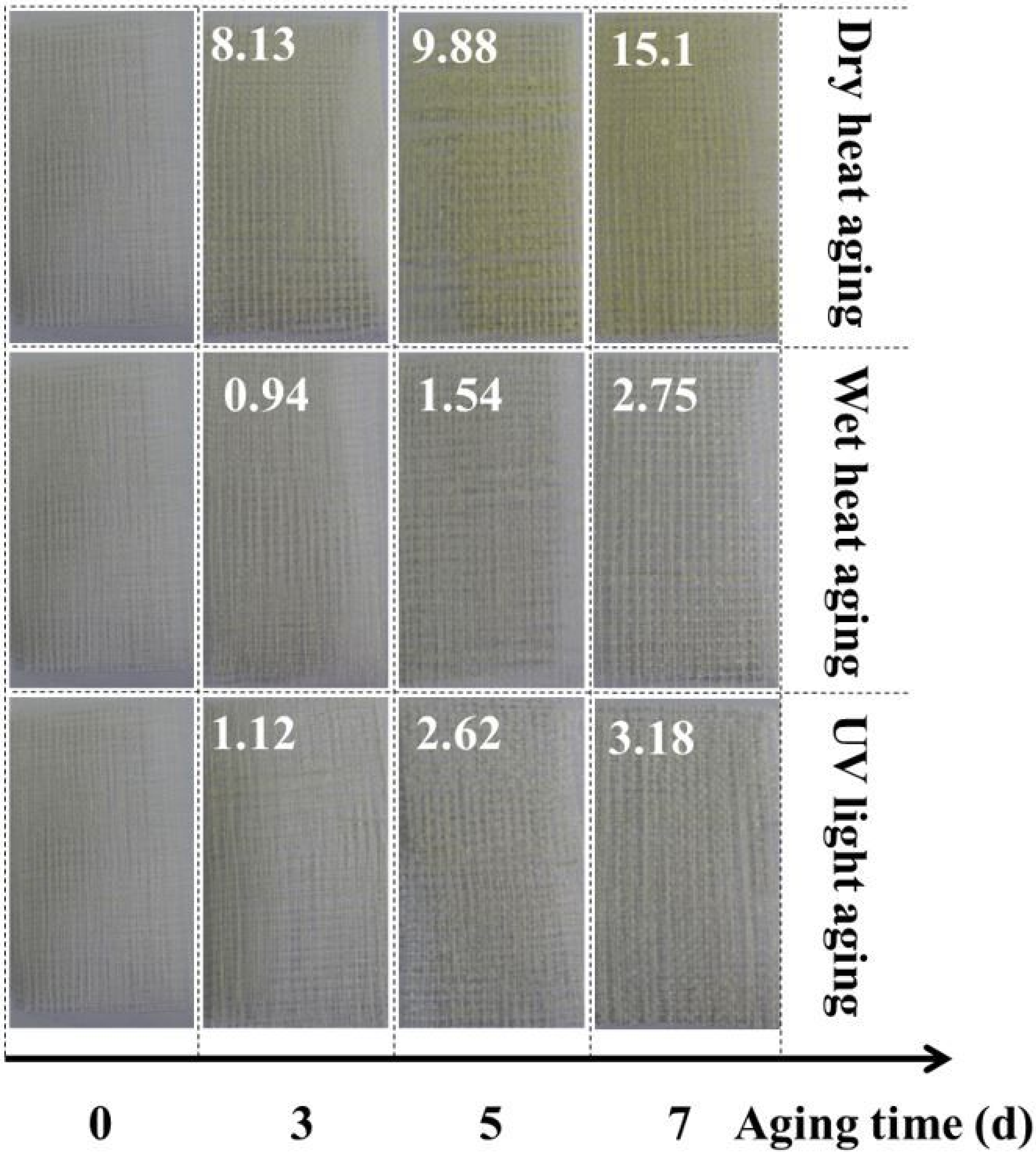

Figure 7

The chromatic aberration data and effect pictures of the reinforcement materials before and after aging several days by using three aging methods. The chromatic aberration data (white numbers) were listed in the effect pictures.

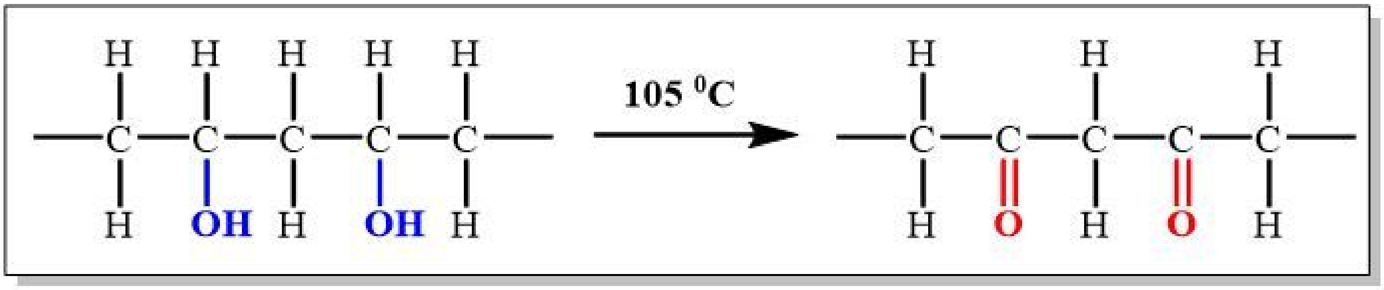

Figure 8

Reaction mechanism of PVA film during heat aging process.

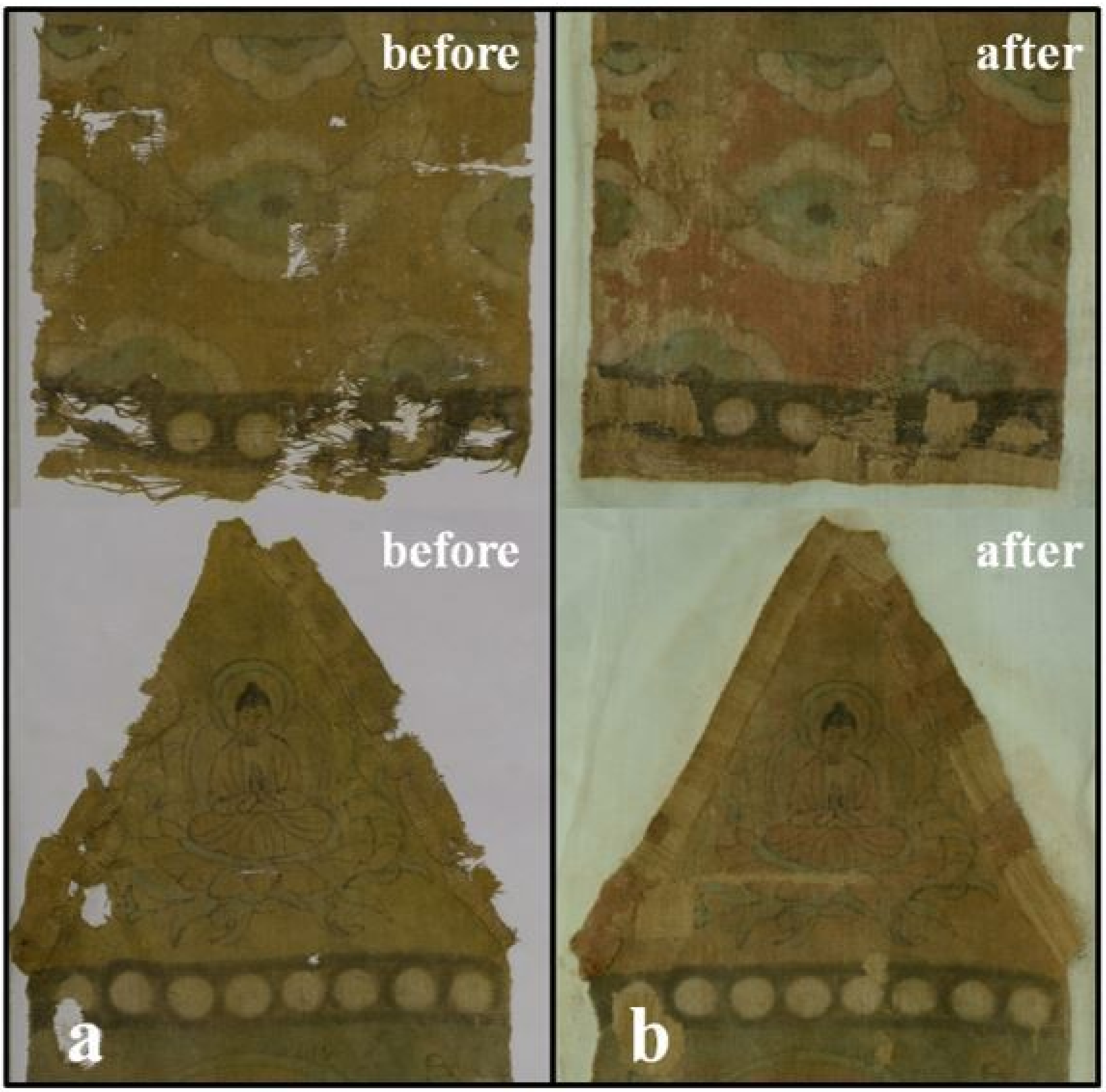

Figure 9

Effect pictures of decayed and rotten hemp fabrics before and after restoration.

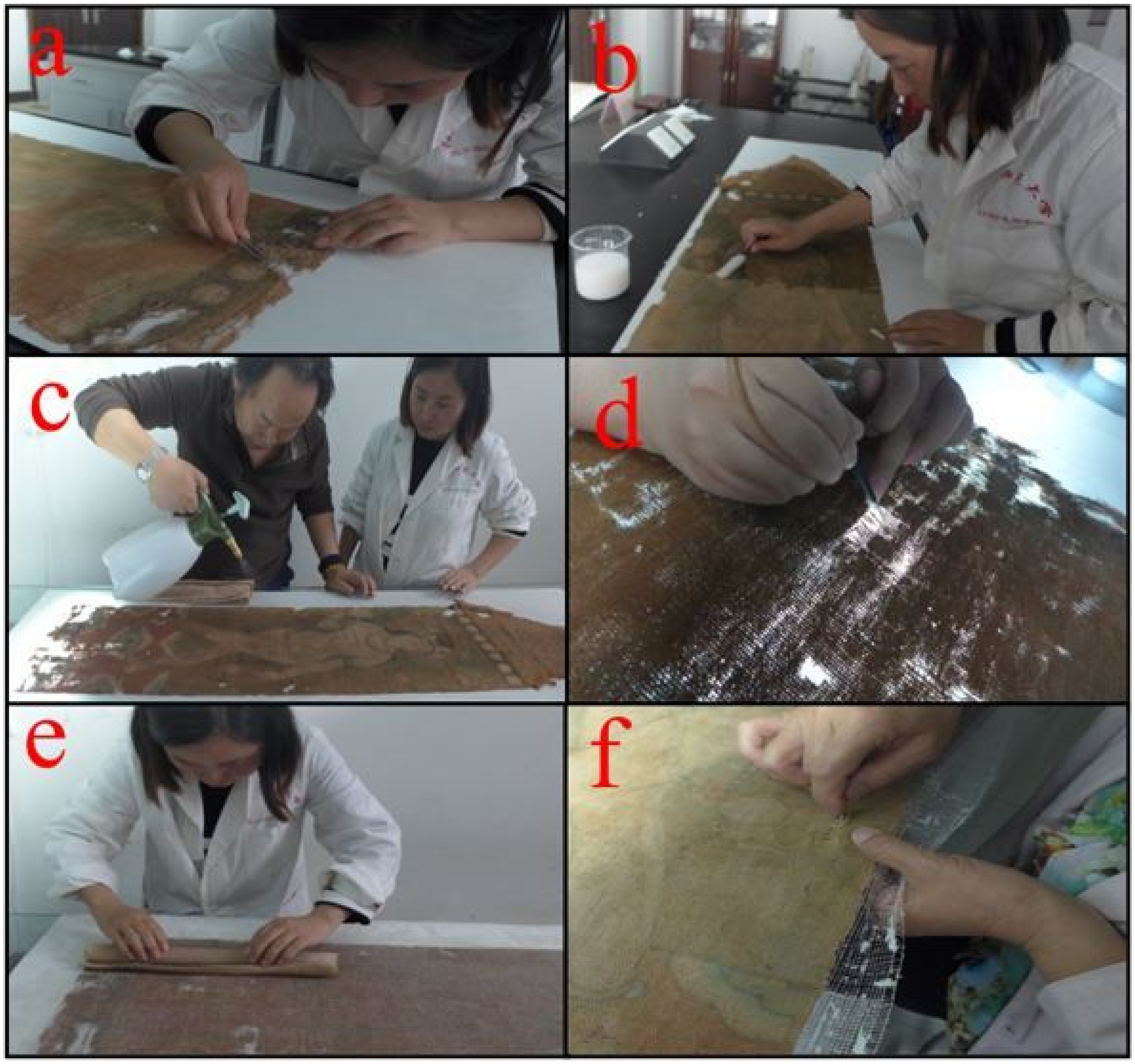

Figure 10

The restoration process of decayed and rotten hemp fabrics.

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