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Creating antique effects on silk fabric

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Abstract

Purpose - The study reported here aimed to reduce the gloss of the surface of silk fabrics, by treating the fabrics with tea and matting agent, to imitate the aging and retro effects of silk artefacts.

Design/methodology/approach - Silk fabrics were treated with different processing techniques. The aged appearance and surface gloss of the silk fabrics were characterised by sensory analysis, measurement of reflectivity, scanning electron microscopy, measurement of brightness and chroma to identify the influential factors.

Findings - The application of matting agent on silk fabrics could reduce the lustre of silk fabrics. Treated with matting agent and tea pigments, silk fabrics could be 'aged' to achieve retro effects within a relatively short period of time. A number of other factors and mechanisms that affect the reflectivity of the silk fabrics were also identified.

Research limitations - There is no definite index to evaluate the antique effect of fabrics.

Practical implications - The method developed through this study provided a simple and practical solution to achieving aging and retro effects on silk fabrics.

Originality/value - The method for reducing the lustre of silk fabrics by treating them with matting agent is novel and the finding of the relationships amongst reflectivity and brightness and chroma is original.

Keywords - Silk fabric, Lustre, Matting agent, Tea pigment, Antique effect

Paper type - Research paper

Introduction

Silk is an important part of everyday life of the ancient Chinese people. Every year, a large

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amount of clothing, utensils and decorations continue to be excavated in China by archaeologists. Among them, there are many kinds of textile cultural relics. (Zhang, 2011) It became clear that silk remained a significant part of Chinese cultural heritage. However, due to their chemical nature, precious silk artefacts are prone to aging and fading, especially when exposed to atmosphere after being excavated.

It has been reported that most of the silk fabrics that have been unearthed were dyed with natural plant dyes. The fabrics are of various colours and have a large degree of fading at a relative humidity above 60%. The fading patterns vary: white and black fabrics have a small chroma value and they do not change greatly even when exposed to high humidity environments for long periods of time. However, red and yellow fabrics have a big difference between their original colour and the long-term colour. Natural climate is an uncontrollable factor. Changes in humidity can cause expansion and contraction of fibre leading to damage of fabric. Even within a container, silk buried underground for a long time is usually embrittled and damaged to varying degrees. The surrounding atmospheric gases such as：N_2, SO_2, O_2, NO, among others, can cause discolouration and fading of the dye (Kong, 2002).

The decline in fabric surface gloss is one of the main manifestations of textile aging. When people look at things, they rely on their own experience. Besides shape and colour under normal conditions, they also look at them under the illumination of light sources such as light bulbs to determine if they have high or low gloss (Zhang, 2000).

The wavelength of the light entering the eye determines the visible colour of the fabric while light reaching retina determines the perception of image. However, for gloss, there is no clear explanation in the literature as to which characteristics of the light is related to it. Ranging from the properties of the fibre itself to the processing of the fibre into fabric, each process affects the gloss of the fabric. Among the many factors affecting the lustre of the fabric, the fibre's intrinsic characteristics are undoubtedly the most important ones. The intensity of the specular reflected light is affected by the surface morphology of the fibre. The smoother the surface morphology of the fibre, the greater the probability of specular reflection as well as a stronger lustre (Kong, 2002). Different types of fibres have numerous differences of cross-sectional morphology that causes variations in the gloss effect of these fibres. Fibres with "Y" and triangular shapes cross-sections exhibits stronger gloss. Silk fabrics tend to have such cross-sectional shapes. For example, the cross-sections of mulberry silk are blunt angled triangles, while those of tussah silk are narrow flat triangles that give them a greater gloss.

The gloss of the surface of fabric is also affected by the fabric's structure and the coverage of the warp and weft yarns. Finishing of fabrics will either increase or weaken the gloss of original fabric depending on the nature of the finishing agent and the finishing process. As far as colour is concerned, brightness and chroma also affect the perception of gloss.

Chinese textile cultural relics are an invaluable cultural heritage that is rich in variety and fine in artisan workmanship. Effective protection of ancient textiles became a matter of great urgency (Kong, 2004), however, the challenge is how to protect and preserve these precious cultural relics permanently. Recent years have seen an emphasis in China on the great importance of the protection of cultural relics that include the textile cultural relics. Physicists and archaeologists have conducted numerous research studies on the effects and impacts of light, heat, temperature and humidity on the aging and the loss of gloss of silk fabric (Wang, 2007; Zhou, 2007; Zhang, 1993).

The protection of Chinese textile relics necessitates extensive research studies which are currently in their infancy. Many literatures indicate that most of the research focuses on the aging mechanism and prolonging the life of silk artefacts. However, some damages are inevitable during the protection and rescue of silk artefacts thus necessitating more research to be done on remediation measures.

This paper attempts to identify a suitable remediation method to protect ancient silk fabrics. This paper suggests that treating silk with natural pigments and matting agents is a simple and effective way to achieve antique effect.

Experimental

The matting agent used in the study reported here is an aliphatic polyurethane light-extinction resin. This kind of matting agent has strong adhesion to artificial leather, creating a permanent matting effect. This type of matting agent had never been used for treatment of silk fabric previously. Inspired by its light-extinction effect on artificial leather, the idea of studying the effects of this type of matting agent on silk was created.

Materials

Key materials employed in the study reported here are listed as follow:

- Silk fabric A: a dyed silk fabric provided by a local textile manufacturer;
- Silk fabric B: an undyed silk fabric provided by a local textile manufacturer;
- Sodium chloride supplied by Tianjin Baishi Chemical Co. Ltd.;
- Glacial acetic acid supplied by Tianjin Zhiyuan Chemical Reagent Co. Ltd.;

- Aliphatic polyurethane matting agent QU-3201B supplied by Foshan Sanhuang Resin Co. Ltd.; and
- Puer tea supplied by Zhejiang Gengxiang Organic Tea Development Co. Ltd.

Instruments and equipment for characterisation

The following instruments and equipment were employed in the study reported here:

- Electronic Balance (HZ Electronic Technology Co. Ltd., Connecticut, USA);
- Electric Forced Air Drying Oven (Tianjin Tester Instrument Co. Ltd., Tianjin, China);
- Constant Temperature Water Bath (Changzhou Guoyu Instrument Manufacturing Co. Ltd., Changzhou, China);
- Electric Ceramic Furnace (Guangdong Xingong Electrical Appliances Co. Ltd., Guangdong, China);
- X-rite Color i5 colourimeter (X-rite, USA); and
- Hitachi TM3000 Scanning Electron Microscope (Hitachi, Japan).

Experiment using Silk Fabric A

Determination of the optimum concentration of matting agent

Small pieces of Silk Fabric A each measuring 5cm × 5cm were cut for use in this series of experiments. Five pieces of the fabrics were each dipped in a matting agent solution containing 1%, 3%, 5%, 8%, and 10% of the matting agent, respectively, for 5 minutes and baked in the Oven at 100°C - 120°C for 2 minutes. The baked fabric pieces were then soaped for 10 minutes in soaping liquor, fully washed and dried in an oven. Based on the reflectivity values, the optimum concentration of matting agent for the treatment of Silk Fabric A was determined.

Treatment with tea

2g of Puer tea was boiled in 200ml of water and left to cool. The resulting mixture was filtered using a glass funnel to separate the tea solution from the solid residue and both the tea liquid and solid tea residue were left to stand at ambient temperature overnight. The tea solution and the solid tea residue, respectively, were then used for dyeing Silk fabric A.

The pH of the tea solution and solid residue was adjusted to 4.0 by adding acetic acid. Two pieces of Silk fabric A labelled Sample 1 and Sample 2, respectively, were dropped into the tea solution and left to stand for one hour (for Sample 1) and for two hours (for Sample 2), respectively, before being removed from the solution and dried in the oven. Similarly, two more silk fabric pieces, labelled Sample 3 and Sample 4 respectively, were placed within tea residue and left to stand for one hour (Sample 3) and for two hours (Sample 4), before they were removed and dried in an oven. Then, the four pieces of silk sample were treated with the matting agent at the optimum concentration determined previously.

Experiment of Silk Fabric B

Determination of extinction and dyeing sequence

1g Puer tea was boiled in 500ml of water for 1 hour and left to cool. Filtration was carried out to separate the tea solution from the residue and both contents left to stand at ambient temperature overnight. The tea solution was then used for dyeing Silk Fabric B.

Two pieces of Silk Fabric B measuring 5cm × 5cm were labelled Sample 1 and Sample 2 respectively. Sample 1 was treated in 30% matting agent followed by baking at 100°C - 120°C for 2 minutes in the electric oven. The treated fabric sample was then soaped in tea solution for a predetermined period of time, washed thoroughly with tap water and dried in the oven. The treated fabric sample was then dipped in the tea dyeing solution at ambient temperature. The dyeing solution was heated to 70°C within 15 minutes and maintained at this temperature for 45 minutes to allow dyeing to take place. After dyeing, the fabric was soaped for 10 minutes, washed thoroughly with tap water and dried in the electric over. Sample 2 was dyed and treated using the same conditions as Sample 1 only that the dyeing was conducted before treatment with matting agent, again under the same conditions.

Orthogonal experiment of matting finishing

To determine the optimal process for the matting finishing, an L9(34) orthogonal experimental design was employed. For this, three parameters were studied including baking temperature, immersion time and concentration of the matting agent as shown in Table I.

(Take in Table I)

The parameters for the dyeing of the matting treated of fabrics, using tea solution, are shown in Table II.

(Take in Table II)

Characterisation methods

Fabric samples having various matting and dyeing treatments were characterised for appearance and surface morphological properties. Relevant methods of characterisation are described below.

Sensory analysis

Sensory evaluation is a useful subjective assessment of the gloss of fabrics based on human visual perception (Shen and Xie, 2017). Thus, each of the silk fabrics concerned with this study was assessed by human observers based on the optical stimulations that their eyes receive under the same conditions. Though it may not be able to distinguish fabrics having similar gloss, sensory evaluation still plays its role in determination of silk gloss because there is no unified criterion for evaluating silk gloss at present yet.

Reflectivity (*R*)

All silk fabrics were folded twice to form four layers. For measurement, they were set to face outwards on an ordinary bleached cotton fabric. The reflectivity of the fabric surface was measured using the X-rite Color i5 colourimeter under a wavelength of 730 nm. The comparison was carried out between the reflectance values of the original silk fabrics A & B and their corresponding samples treated under different conditions and processes.

Scanning Electron Microscopy (*SEM*)

The Hitachi TM3000 scanning electron microscope was used to scan the samples at the rate of 0.5Hz at ambient conditions. The surface morphology of the original sample and the treated samples were obtained and compared.

Brightness and chroma

All silk fabrics were folded twice to form four layers. They were set to face outwards on an ordinary bleached cotton fabric for measurement of the Brightness L*and chroma C* values using the X-rite Color i5 colorimeter.

Results and discussion

Relevant results are detailed in this section. Based on the results obtained, the gloss of silk fabrics under different treatment conditions and processes was assessed and the relationship between gloss, brightness and chroma was explored.

Sensory analysis

(Take in Figure 1)

(Take in Figure 2)

Figure 1 shows photographs of the untreated silk fabric A and Samples 1 – 4 of matt finished silk fabric A. Figure 2 shows photographs of the untreated silk fabric B and Samples 1 – 4 of matt finished silk fabric B. From Figure 1 and Figure 2, it can be seen from the pictures that the results of different processes are different. The colour and gloss are different. It was evident that the gloss of the fabrics after gloss extinction treatment and tea dyeing decreased. The colour of the dyed fabrics also varied following different treatment and dyeing. According to the observation of several researchers, it is generally believed that 3 in Figure 1 more like aged silk. The treated fabric A look old than treated fabric B. This may be related to the fact that fabric A has been processed in the factory.

Reflectivity

The reflectivity of fabric surface was measured using the colourimeter The smaller the reflectivity, the worse the gloss and the greater the matting effect. It was found that the treatment of a matting agent did cause the reflectivity to change significantly. Detailed results are shown and discussed below.

Silk fabric A treated with different concentrations of the matting agent

The relevant reflectivity results are shown in Table III.

(Take in Table III)

It can be seen, from Table III, that when other conditions were kept the same, the reflectivity of fabric surface decreased with the increase in the concentration of the matting agent. The decrease in reflectivity became less pronounced when the concentration of the matting agent reached 5%. To save cost, the optimum concentration of the matting agent to use in ensuing experiments was set at 5%. Based on the results shown in Table III, the optimum treatment conditions were set at: dipping fabric in 5% matting agent QU-3201B, then baking at 120°C for 2 minutes, soaping for 10 minutes, washing thoroughly and drying.

Silk fabric A dyed with tea

The relevant reflectivity results of silk fabric A dyed with tea are shown in Table IV.

(Take in Table IV)

It can be seen, from Table IV, that the reflectivity of the sample decreased after being dyed with either tea water or tea residue and treated with the matting agent. The silk samples dipped in tea water absorbed the colour of the tea water while those covered with tea residue got exposed to impurities in the residue consisting of Tea residue contains tea polyphenols, free amino acids, ash, crude fat, crude protein, crude fibre and water etc. Tea residue contains tea polyphenols, free amino acids, ash, crude fat, crude protein, crude fibre and water, etc. (Zheng, 2015). The reflectivity of the silk samples treated with tea residue was lower than that of samples dyed with tea water. Under constant environment conditions, the longer the sample was treated in either the tea water or tea residue, the lower their reflectivity. Though reflectivity could further be further reduced when samples were treated for longer time, two hours of treatment were deemed to have meet the desired result thus making the method simple and fast as originally intended.

Reflectivity Test result of Silk fabric B

It was observed that the matting effect was unstable when the samples were first treated with tea and then with a matting agent: the gloss change was irregular, the colour change was significantly different, and the reproducibility of the experiment was extremely low. When samples were first matted and then dyed with tea, both the matting effect and the colour change had a high reproducibility. Thus, this order of treatment/dyeing of fabrics was used for the subsequent experiments. Optimum conditions and processes for matting were selected by orthogonal experiment shown in Table V.

(Take in Table V)

Similarly, the results of dyeing by tea after matting are shown in Table VI.

(Take in Table VI)

It can be seen from the orthogonal experiment results shown in Table V that for the three factors of Baking temperature, Immersion time and Concentration, the value that represents the difference between the maximum value and the minimum value of k for each factor, R, of Immersion time is the maximum value (3.750); the R of Baking temperature is the minimum value (1.654). This indicates that the most important factor affecting reflectivity is the impregnation/immersion time, followed by the concentration of the matting agent and baking temperature. The lower the experimental index (Reflectivity) was, the better the results. Therefore, the optimum conditions selected were: 5 minutes impregnation time, 50% concentration of matting agent and a baking temperature of 120°C, i.e. Process 7. These conditions of Process 7 were used for matting finishing in subsequent experiments.

It can be seen from Table VI that although the matting process was the same, the reflectivity changed greatly after dyeing with tea in different conditions. The reflectivity decreased with the increase in temperature of dyeing. Reflectivity was the lowest when the dyeing temperature was 60°C under the experimental conditions.

Surface morphology of fabric samples

The surface morphology of silk fabric B before and after matting finishing was observed under a scanning electron microscope (SEM). The images before and after finishing are shown in Figure 3.

(Take in Figure 3)

SEM images clearly showed that the original silk fabric B surface was smooth while that of the treated sample was uneven and rough. The dried matting agent on the surface of the silk fabric was uneven, making its surface rough. This weakened the mirror reflection and enhanced the diffuse reflection to achieve the matting effect. After matting treatment, the surface of silk fabric B had a film covering the original smooth silk surface which made the silk appear less glossy. Even after washing, the film still existed.

Brightness and saturation

The brightness values (L*) of the original silk fabric A and silk fabric B were 90.24 and 91.55 while their saturation values (C*) were 9.94 and 4.11, respectively. These readings were used as a standard and used to determine the brightness and saturation differences of the treated the sample fabrics using Equations 1 and 2 (Dong *et al.*, 2007).

$$\Delta L^{*}=L^{*}_{sp} - L^{*}_{std} \quad (1)$$

$$\Delta C^{*}=C^{*}_{sp} - C^{*}_{std} \quad (2)$$

Where, sp denotes sample and std denotes standard.

Brightness and saturation of silk fabric sample A

The brightness and saturation difference of silk fabric A sample after dyeing and matting finishing are shown in Table VII.

(Take in Table VII)

Brightness and saturation of silk fabric sample B

The brightness and saturation difference of silk fabric sample B after matting finishing and dyeing are shown in Table VIII.

(Take in Table VIII)

It can be seen, from Tables VII and VIII, that the brightness of the treated sample decreased (the difference between the treated samples and the standard samples is negative), and their chroma increased.

Relationship between reflectivity and brightness or chroma

The reflectivity data in Tables IV and VI were plotted against the corresponding brightness and chroma values in Tables VII and VIII. The relationship between brightness and reflectivity as well as that between chroma and reflectivity was explored. Taking the reflectivity as x and the brightness as y, the resultant linear equation was: $y=0.9544x+6.849$ (Figure 4). Similarly, taking the reflectivity as x and the chroma as y, the resultant linear equations were $y=-1.4115x + 129.01$ for silk fabric A and $y=-0.5781x + 53.725$ for silk fabric B (Figure 5). The reflectivity values of silk fabrics A & B are proportional to their brightness while they are inversely proportional to their chroma.

(Take in Figure 4)

(Take in Figure 5)

Conclusion

Based on sensory analyses, it was found that, for matting finished silk fabric A, there was little lustre which increased the appearance of age while for matting finished silk fabric B, although the lustre was also dimmed, the fabric didn't look obviously old.

The matting agent had a stronger effect on silk fabric A compared to silk fabric B; the reflectivity decreased to the lowest limit when the concentration of the agent was 5%. The reflectivity of silk fabric A treated with tea residue was lower than that treated with tea water. For fabric B, the optimum gloss extinction conditions were determined by orthogonal experiment to be: 50% concentration of matting agent, impregnation time of 5 minutes and baking at 120°C for 2 minutes. In addition, it was found that the reflectivity of the silk fabric sample decreased when dyeing temperature was increased.

Based on the graphs and equations of reflectivity, brightness or chroma, it was clear that reflectivity is proportional to brightness and inversely proportional to chroma, with the materials studies in the experiments concerned.

This study was the first to apply matting agent on silk fabrics to reduce the lustre of the fabric. The matting effect was evident. It was found that by combining the matting treatment and tea dyeing, aging and retro effects on silk fabrics were achieved within a short period of time.

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Table I Factors studied in the orthogonal experiment to optimise matting finishing

Level	Factor		
	Baking temperature (°C)	Immersion time (minutes)	Concentration (%)
1	100	5	30
2	110	10	40
3	120	15	50

Table II Parameters of the dyeing process with Puer tea

Experiments	1	2	3	4
Temperature (°C)	Ambient	40	60	70
Time (hours)	1			
pH	4			
Ratio	1:200			

Table III Reflectivity of Silk Fabrics A treated with the matting agent at different concentrations

Concentration of the matting agent (%)	Reflectivity (%)
1	84.39
3	83.92
5	82.21
8	82.17
10	82.20

Table IV Reflectivity of Silk Fabric A dyed with tea

Sample	Reflectivity (%)
Original Silk fabric A	84.46
Dyed with tea water for 1 hour	76.38
Dyed with tea residue for 1 hour	73.32
Dyed with tea water for 2 hours	75.87
Dyed with tea residue for 2 hours	72.85

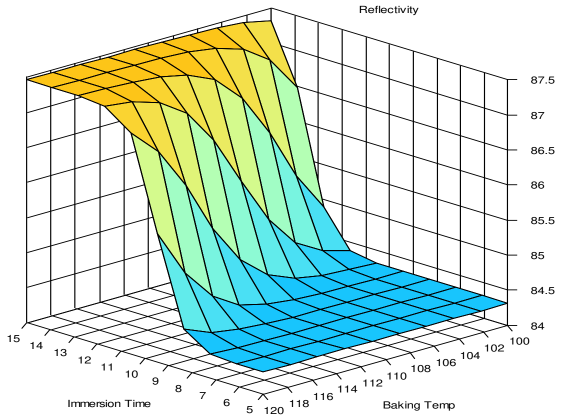
Table V Results of orthogonal experiment of matting finishing

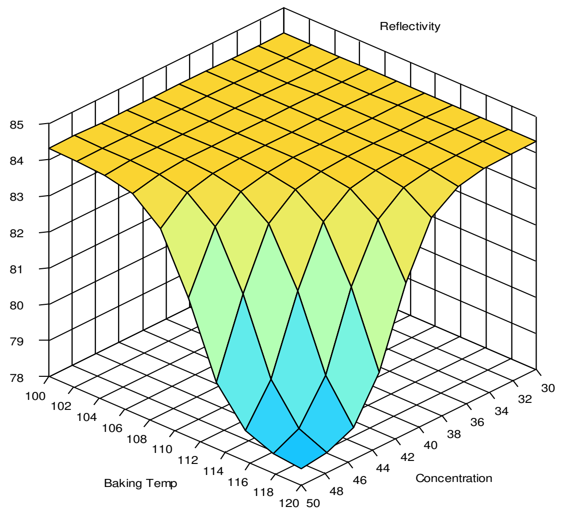
	Baking temperature (°C)	Immersion time(minutes)	Concentration (%)	Reflectivity (%)
1	100	5	30	82.82
2	100	10	40	82.77
3	100	15	50	88.54
4	110	5	40	87.04
5	110	10	50	82.21
6	110	15	30	86.16
7	120	5	50	78.41
8	120	10	30	87.22
9	120	15	40	84.82
K1	254.13	248.27	256.20	—
K2	255.41	252.20	254.63	—
K3	250.45	259.52	249.16	—
k1	84.710	82.757	85.400	—
k2	85.137	84.067	84.877	—
k3	83.483	86.507	83.053	—
R	1.654	3.750	2.347	—

Note:

K1 – represents the sum of the experimental results corresponding to level 1 for each factor;
K2 – represents the sum of the experimental results corresponding to level 2 for each factor;
K3 – represents the sum of the experimental results corresponding to level 3 for each factor;
k1 – represents the average of K1; k2 –represents the average of K2; k3 – represents the average of K3;
R – is the difference between the maximum value and the minimum value of k for each factor.

3D Plots from Table V


Reflectivity
87.5
87
86.5
86
85.5
85
84.5
84
15
14
13
12
11
10
9
8
7
6
5
Immersion Time
120
118
116
114
112
110
108
106
104
102
100
Baking Temp


Reflectivity
85
84
83
82
81
80
79
78
100
102
104
106
108
110
112
114
116
118
120
Baking Temp
50
48
46
44
42
40
38
36
34
32
30
Concentration

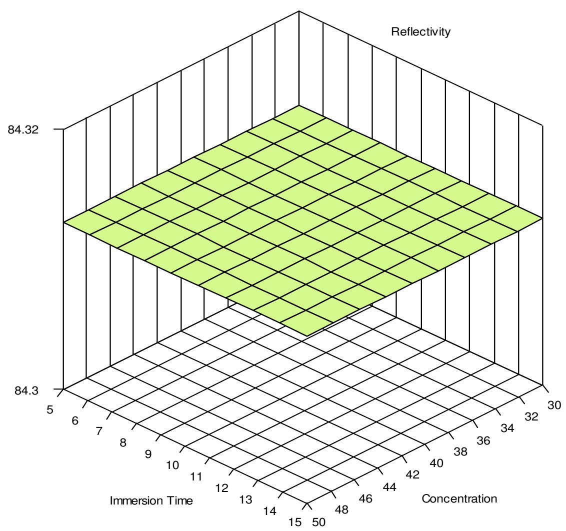

Reflectivity
84.32
84.3
5
6
7
8
9
10
11
12
13
14
15
Immersion Time
50
48
46
44
42
40
38
36
34
32
30
Concentration

Table VI Results of dyeing with tea after matting finishing

Sample	Reflectivity (%)
Original silk fabric B	85.46
1	67.38
2	61.97
3	52.15
4	54.34

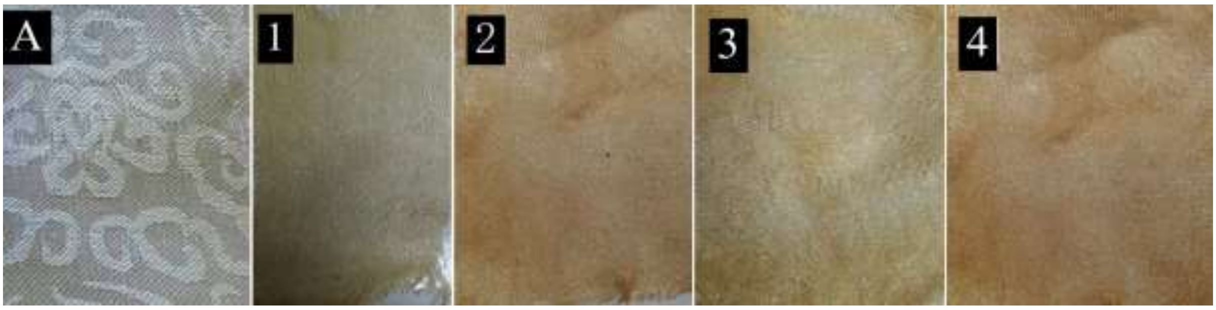
Table VII Changes in brightness and saturation of Silk Fabric A samples

Sample	Changes in brightness (ΔL*)	Changes in saturation (ΔC*)	Brightness (L*)	Saturation (C*)
Dyed with tea water (1 hour)	-14.50	10.98	76.24	20.83
Dyed with tea water (2 hours)	-15.07	11.44	75.17	21.83
Dyed with tea residue (1 hour)	-14.22	15.47	76.02	25.41
Dyed with tea residue (2 hours)	-15.09	15.62	75.15	26.62

Table VIII Brightness and saturation differences of silk fabric B sample

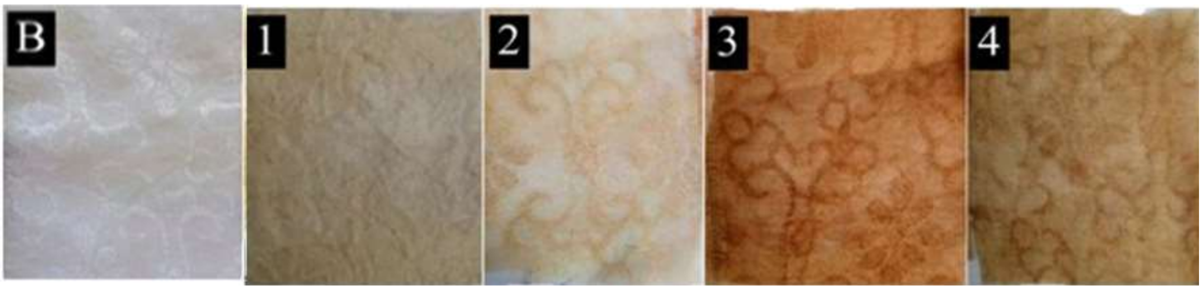
Sample	Brightness difference (ΔL*)	Saturation difference (ΔC*)	Brightness (L*)	Saturation (C*)
1	-21.82	10.70	69.73	14.81
2	-20.51	14.60	71.04	18.71
3	-36.07	19.47	55.48	23.58
4	-31.58	17.57	59.97	21.68

Figure 1 Photographs of Silk fabric A and finished Silk fabric A samples (1 – 4)



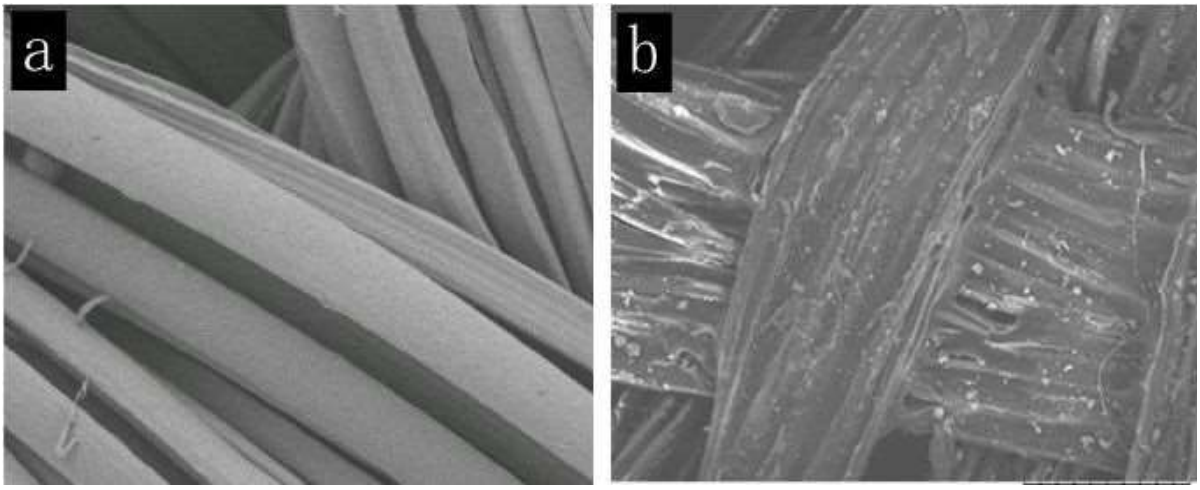
Note: A – Untreated silk fabric A; 1 – silk fabric A dyed in tea solution for 1 hour; 2 – silk fabric A dyed in tea solution for 2 hours; 3 – silk fabric A treated in tea residue for 1 hour; and 4 – silk fabric A treated in tea residue for 2 hours（1-4 were all treated with the matting agent after treated by tea）

Figure 2 Pictures of Silk fabric B and finished Silk fabric B samples (1 – 4)



Note: B – untreated silk fabric B; 1 - silk fabric B dyed in tea solution at room temperature; 2 - silk fabric B dyed in tea solution at 40℃; 3 - silk fabric B dyed in tea solution at 60℃ and 4 - silk fabric B dyed in tea solution at 70℃. （1-4 were all treated with the matting agent before treated by tea）

Figure 3 SEM image of Silk fabric B before and after matting finishing



a - original Silk fabric B; b - Silk fabric B treated with matting agent

Figure 4 Diagram of correlation between brightness (L*) and reflectivity (R)

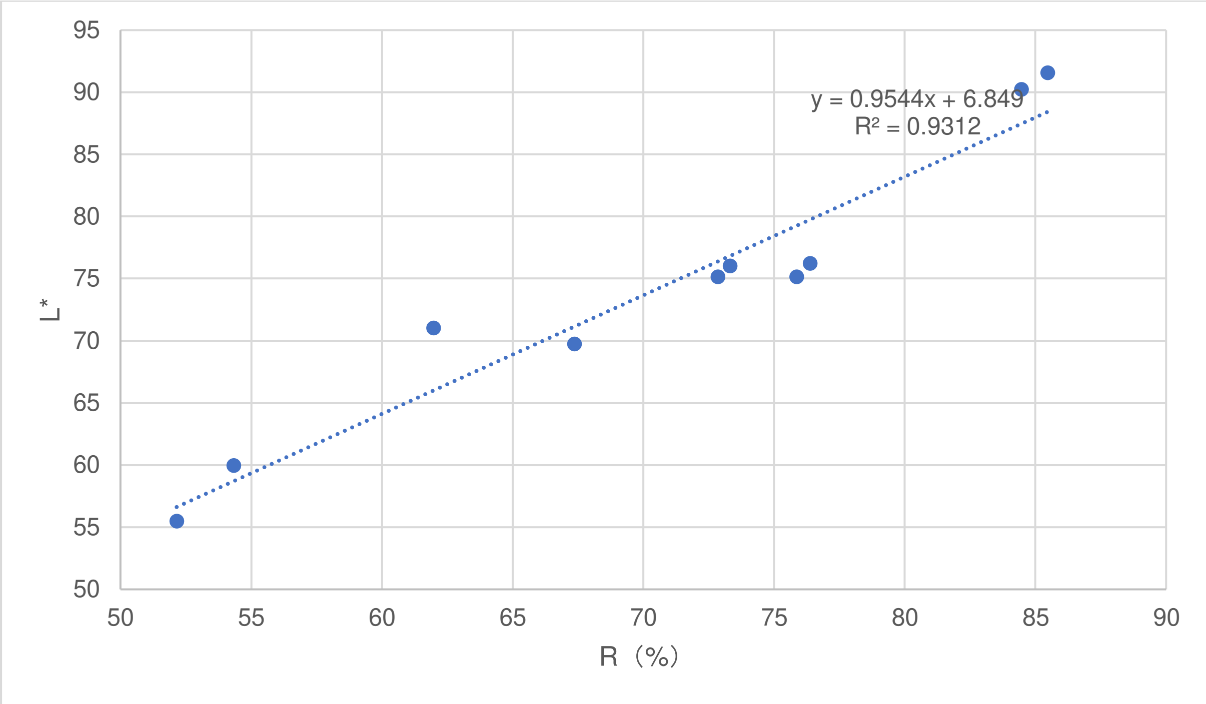


Figure 5 Diagram of correlation between saturation (C*) and reflectivity (R)