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Article

# Influence of the Bottom Color Modification and Material Color Modification Process on the Performance of Modified Poplar

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**Abstract:** According to the old surface coating process of European and American furniture, the surface of modified poplar is first differentiated pre-treatment, and then the bottom color modification and material color modification are respectively applied to the modified poplar after the surface differentiation treatment. The visual physical quantity and physical and chemical properties were measured and compared with mahogany, which is commonly used in old furniture in Europe and America to explore the effect of colorants and coloring steps, as well as different surface pretreatments on the coloring effect. Finally, it is concluded that continuous coloring operations can narrow the difference in brightness and red color value in the coloring layer of modified poplar and mahogany. Continuous coloring operations increase the difference between the yellow-green color values of modified poplar and mahogany. Therefore, the coloring difference between modified poplar and mahogany was affected by the colorant and coloring steps. Through color accumulation, the gap between the two in the target color coloring effect can be reduced, thereby reducing the difference between the coloring effect of modified poplar and mahogany.

**Keywords:** modified poplar; material color modification; bottom color modification; mahogany; distressing effect of color



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## 1. Introduction

Modified poplar is a fast-growing wood with poor wood properties, but its growth rate is relatively fast. Mahogany is generally used as a high-end furniture material, with good wood color and beautiful texture, but its growth rate is slower, so it is hoped that the modified poplar can achieve the same effect as mahogany, improving the application value of modified poplar.

The antique finishing process uses dyes or pigments to attach multiple times to the paint, and different special techniques to give the furniture a sense of history [1–6]. The distressing effect is reflected in the control of the surface color. This control includes not only the type of color, but also the layered color processing. From the initial color modification and background color paving of the base material to the subsequent color correction, layering and shading, this series of coloring processes have strict technical requirements [7–9]. The material color modification and the bottom color modification are the processes of coloring directly on the wood surface, and the coloring effect is related to the properties of the wood surface. Sanding can give the wood a smooth surface. Brushing the Didebao primer can seal the tiny pipe holes in the wood to a certain extent, improving the surface performance of the wood, and it is very important for the adhesion of the subsequent paint [10,11].

The bottom color modification is the first overall coloration of the surface of the furniture, and it is the basic "setting" for the color of the product. For example, the walnut color paint finish process often uses two coloring substances, commonly known as "red water" and "yellow water". "Yellow water" is a kind of brown-yellow paint made of a mixture of pigments and dyes. It is often sprayed after the red water, mainly to highlight the texture of the wood. The material color modification is an important process step for obtaining richer and richer colors on the surface of European and American furniture, which is a necessary process to make the paint surface the most "colorful". The pigment used is Grace, also known as antique paint, which is an oily pigment colorant, and uses its own translucency to reduce the brightness of the product surface and form a layered contrast effect of light and dark [12–14]. Fast-growing wood modification is to change the properties of wood through physical, chemical or biological methods, so that it can reach a certain technological production index [15–18]. This technology has been greatly developed at home and abroad, and the research results are quite fruitful. Especially in the furniture production industry, more and more furniture has begun to try to use modified fast-growing wood to replace more commonly used wood, and it has won some consumers' love and welcome and good market favor.

Baysal et al. [19] studied the effect of accelerated weathering on the surface properties of Scots pine specimens impregnated and coated with synthetic and polyurethane varnish. The results show that weathering causes the gloss of the sample to decrease. The positive value of the color coordinate means that the wood surface changes from its original color to light red and light yellow. Gong et al. [20] selected heat-treated white poplar and untreated white poplar to compare their physical properties. The results showed that heat treatment significantly improved the dimensional stability of poplar and reduced the mechanical properties to a certain extent. However, the mechanical properties of the heat-treated poplar specimens are still greater than that of the unheated poplar specimens. The physical properties of heat-treated samples and control samples were tested by Korkut et al. [21] under different heat treatment conditions. The results show that as the temperature and treatment time increase, the values of density, swelling degree and surface roughness decrease. Its properties can be changed through appropriate heat treatment technology, and the Turkish hazel wood can be better utilized.

However, there is still little domestic and foreign research on the effect of material color modification and bottom color modification on the surface properties of modified poplar wood. Poplar wood modified by physical, chemical or other methods can have better properties. The poplar after modification is called "modified poplar". Therefore, the author started with modified poplar as a new material, and carried out the color correction and material color correction respectively. We aimed to discuss the visual physical quantity and physical and chemical properties of modified poplar wood after different surface pretreatments are measured, and then the influence of colorants, coloring steps and different surface pretreatments on the coloring effect are analyzed.

## 2. Experiment

### *2.1. Materials*

The main components of the Didebao primer are water, oil, resin, pigment, thinner and auxiliary materials (drier, curing agent, plasticizer and moisture-proof agent) provided by Mingshida Co., Ltd. (Taian, China). The modified poplar (Populus tomentosa Carr) (sawed transversely, size 150 mm × 80 mm × 20 mm, diameter section) and mahogany (Swietenia macrophylla King) (size 150 mm × 80 mm × 20 mm, diameter section) were provided by Jiayue Wood Industry Co., Ltd. (Dezhou, China). This is a physical modification. The specific steps of poplar wood modification are as follows. First, a modifier of modified poplar is prepared. The modifier is a mixture of urea dissolved in water and antimony trioxide dissolved in glacial acetic acid. Next, the poplar wood is processed into small pieces of 150 mm × 80 mm × 20 mm and placed in the modifier (liquid) for 4 h. This process must ensure that the wood pieces are at a pressure of 3.0 MPa under vacuum. Finally, the modified poplar block is placed in a drying oven at 90 °C for 24 h to ensure that the modified poplar can reach an equilibrium moisture content of 8.0%. The main component of red paint water is 68% color paste pigment, 71% solid content, and the main component of the ingredients is 4.35% disperse red 3B, 26.09% N-dimethylformamide, 34.8% cyclohexanone, 30.41% butyl acetate, 4.35% Q22-1 nitro varnish, provided by Bixiang Wood Co., Ltd. (Ganzhou, China). The main component of yellow paint water is 68% color paste pigment, 71% solid content, and the main component of the ingredients is 4.48% dispersible yellow RGFL, 29.85% N-dimethylformamide, 41.79% cyclohexanone, 23.88% butyl acetate ester, provided by Bixiang Wood Co., Ltd., Ganzhou, China. The main components of Grace are 53.59% refined linseed oil, 10% extender pigment calcium carbonate, 15% color pigment C.IPigment Red 101 77491, 20% turpentine solvent, 0.5% dispersant, 0.3% organic drier, 0.1% antioxidant, 0.5% cobalt salt, 0.01% manganese salt, provided by Nippon Co., Ltd., Singapore (as shown in Table 1).

The bottom modification color is the main color finally presented on the surface of the furniture. In the experimental design, the walnut color is used as the standard color for the experiment. The walnut-colored lacquer is beautiful and has clear wood grain, which is more popular in high-end furniture. Mahogany can show the effect of walnut-colored lacquer, so it is hoped that the modified poplar can also show the effect of walnut-colored lacquer. In the bottom modification color, the walnut paint surface needs to use two reagents at this stage, namely permeable red paint water and permeable yellow paint water. The two reagents are sprayed. Before repairing the color of the material, nitro primer is sprayed on the area where the base color is repaired. The Grace used for the color repair of the material is an oil-based paint, which uses a wipe operation method.

### 2.2. Preparation of Sample

The size of the test piece is 150 mm × 80 mm × 20 mm, and the test piece production instructions are shown in Table 2 (Preparation of sample).

**Table 1.** The main component of species.

| Species | Enterprise | Origin | The Main Component |
|---|---|---|---|
| Didebao | Mingshida Co., Ltd. | Taian, China | water, oil, resin, pigment, thinner, auxiliary materials |
| Modified poplar | Jiayue Wood Industry Co., Ltd. | Dezhou, China | – |
| Mahogany | Jiayue Wood Industry Co., Ltd. | Dezhou, China | – |
| Red paint water | Bixiang Wood Co., Ltd. | Ganzhou, China | 4.35% disperse, 26.09% N-dimethylformamide, 34.8% cyclohexanone, 30.41% butyl acetate, 4.35% Q22-1 nitro varnish |
| Yellow paint water | Bixiang Wood Co., Ltd. | Ganzhou, China | 4.48% dispersible yellow RGFL, 29.85% N-dimethylformamide, 41.79% cyclohexanone, 23.88% butyl acetate ester |
| Grace | Nippon Co., Ltd. | Singapore | 53.59% refined linseed oil, 10% extender pigment calcium carbonate, 15% color pigment C.IPigment Red 101 77491, 20% turpentine solvent, 0.5% dispersant, 0.3% organic drier, 0.1% antioxidant, 0.5% cobalt salt, 0.01% manganese salt |

**Table 2.** Preparation of sample.

| Sample (#) | Specific Instructions |
|---|---|
| 1 | modified poplar—don't brush primer—no sanding—1/3 bottom modification color—1/3 material modification color |
| 2 | modified poplar—brush primer—no sanding—1/3 bottom modification color—1/3 material modification color |
| 3 | modified poplar—brush primer—180# sanding—1/3 bottom modification color—1/3 material modification color |
| 4 | modified poplar—brush primer—240# sanding—1/3 bottom modification color—1/3 material modification color |
| 5 | modified poplar—brush primer—320# sanding—1/3 bottom modification color—1/3 material modification color |
| 6 | modified poplar—brush primer—400# sanding—1/3 bottom modification color—1/3 material modification color |
| 7 | mahogany—brush primer—320# sanding—1/3 bottom modification color—1/3 material modification color |

Specimens 1–7 are mainly used to study the effects of different pretreatment methods on the coloring. In order to compare different angles and aspects, in the production process of specimens 1–7, the method of partition coloring was creatively adopted. The coloring effect is shown in Figure 1.

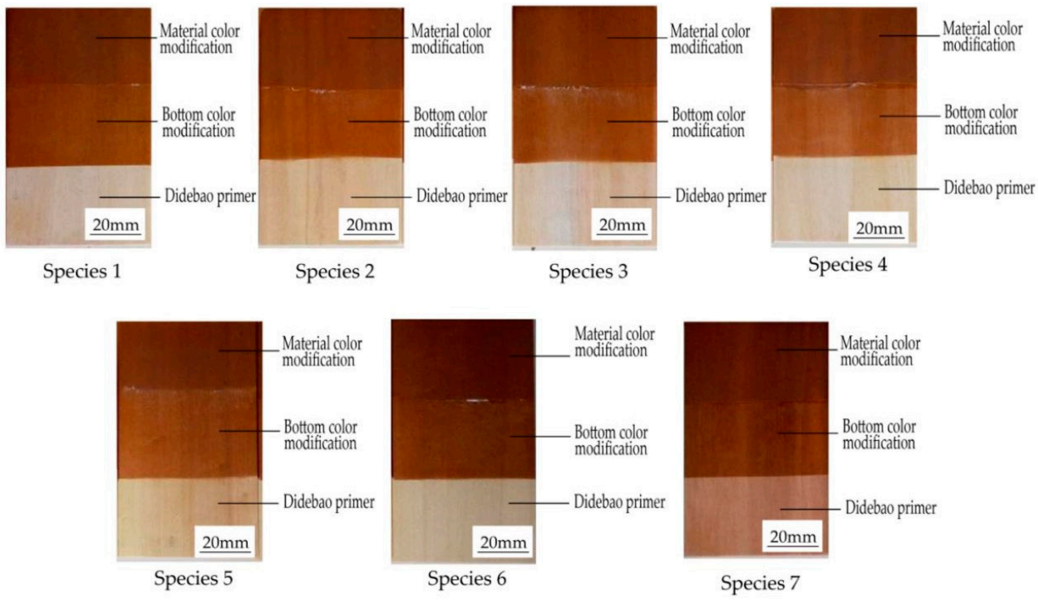


**Figure 1.** Coloring effect of test piece by area.

### 2.3. Testing and Characterization

In order to ensure the same "coating amount" for the bottom color modification and the material color modification on the surface of the test piece, both were sprayed with a spray gun (provided by Baoli Co., Ltd., Taiwan, China), and sprayed from the vertical direction. The spray gun air pressure was controlled to 0.5 MPa, and the nozzle paint output was 200 mL/min, the spraying width was 180 mm, the spraying distance was 200 mm, and the number of spraying passes was one.

A handheld spectrophotometer (provided by Yingsheng Hengtai Technology Co., Ltd., Beijing, China) was used to test the color. Measuring aperture is 8 mm. Measurement data included CMYK, AdobeRGB (1998), sRGB, HTML, $L^*a^*b$, XYZ, etc. The light source was N.Daylight.D65 (provided by Yingsheng Hengtai Technology Co., Ltd., Beijing, China), which means that the device can simulate the pattern of daily sunlight to achieve the purpose of identifying colors more naturally. The light source was vertically incident. In order to reduce the error, three test points were respectively taken in the three areas of the test piece, and each test point was measured twice, and finally the average value was taken. During the operation, the instrument's lighting hole was close to the surface of the object and kept stable so that no light leaked or entered the light. After the measurement, the instrument automatically calculated the relevant data and recorded it in time.

## 3. Results and Discussion

### 3.1. Analysis of Factors Affecting Coloring Process Performance

The wood density is 0.36 g/cm$^3$ and wood moisture content is 18.5%. The measurement results of each area of each test piece are shown in Table 3. The data in Table 3 is directly read from the testing instrument, which means that the direct color parameters are brightness ($L^*$), red-green axis chromaticity index ($a^*$), and yellow-blue axis chromaticity index ($b^*$). After sorting, the comprehensive color parameters of each area of the test piece are obtained, as shown in Table 4.

**Table 3.** Color measurement values for each area of the test piece.

| Sample (#) | Area | *L** | *a** | *b** | Δ*E** |
|---|---|---|---|---|---|
| 1 | wood color | 72.01 ± 1.9 | 10.95 ± 0.25 | 19.52 ± 0.46 | – |
| | bottom modification color | 43.22 ± 1.05 | 26.04 ± 0.6 | 34.69 ± 1.35 | 35.87 |
| | material modification color | 31.69 ± 0.74 | 28.97 ± 0.71 | 29.61 ± 0.7 | 12.93 |
| 2 | wood color | 62.42 ± 1.56 | 9.17 ± 0.22 | 23.65 ± 0.59 | – |
| | bottom modification color | 43.22 ± 1.08 | 26.04 ± 0.65 | 34.69 ± 0.86 | 27.85 |
| | material modification color | 31.92 ± 0.79 | 32.59 ± 0.81 | 27.12 ± 0.67 | 15.09 |
| 3 | wood color | 71.30 ± 1.77 | 9.09 ± 0.22 | 17.93 ± 0.44 | – |
| | bottom modification color | 40.45 ± 1.01 | 20.74 ± 0.518 | 35.26 ± 0.88 | 37.26 |
| | material modification color | 31.69 ± 0.79 | 28.97 ± 0.72 | 29.61 ± 0.74 | 13.28 |
| 4 | wood color | 63.90 ± 1.59 | 7.35 ± 0.18 | 18.07 ± 0.45 | – |
| | bottom modification color | 41.87 ± 1.04 | 9.97 ± 0.24 | 36.62 ± 0.91 | 28.92 |
| | material modification color | 30.09 ± 0.75 | 26.96 ± 0.67 | 28.92 ± 0.72 | 22.06 |
| 5 | wood color | 63.73 ± 1.59 | 12.23 ± 0.3 | 23.51 ± 0.58 | – |
| | bottom modification color | 38.57 ± 0.96 | 26.16 ± 0.65 | 34.55 ± 0.86 | 30.80 |
| | material modification color | 33.30 ± 0.83 | 30.97 ± 0.77 | 30.29 ± 0.77 | 8.31 |
| 6 | wood color | 56.96 ± 1.42 | 8.97 ± 0.22 | 19.03 ± 0.47 | – |
| | bottom modification color | 35.27 ± 0.88 | 27.80 ± 0.69 | 33.08 ± 0.82 | 31.98 |
| | material modification color | 29.54 ± 0.72 | 34.75 ± 0.85 | 17.76 ± 0.43 | 17.77 |
| 7 | wood color | 50.39 ± 1.25 | 14.09 ± 0.34 | 23.46 ± 0.57 | – |
| | bottom modification color | 30.31 ± 0.75 | 30.58 ± 0.76 | 26.44 ± 0.66 | 26.15 |
| | material modification color | 31.49 ± 0.78 | 29.64 ± 0.74 | 19.91 ± 0.48 | 6.70 |

**Table 4.** Chromatic parameters for modified poplar by the colorant of European and American furniture.

| Sample (#) | Area | *L** | *a** | *b** | Δ*L** | Δ*a** | Δ*b** | Δ*E** |
|---|---|---|---|---|---|---|---|---|
| 1 | wood | 72.01 | 10.95 | 19.52 | – | – | – | – |
| | bottom | 43.22 | 26.04 | 34.69 | −28.79 | 15.09 | 15.17 | 35.87 |
| | material | 31.69 | 28.97 | 29.61 | −11.53 | 2.93 | −5.08 | 12.93 |
| 2 | wood | 62.42 | 9.17 | 23.65 | – | – | – | – |
| | bottom | 43.22 | 26.04 | 34.69 | −19.2 | 16.87 | 11.04 | 27.85 |
| | material | 31.92 | 32.59 | 27.12 | −11.3 | 6.55 | −7.57 | 15.09 |
| 3 | wood | 71.3 | 9.09 | 17.93 | – | – | – | – |
| | bottom | 40.45 | 20.74 | 35.26 | −30.85 | 11.66 | 17.33 | 37.26 |
| | material | 31.69 | 28.97 | 29.61 | −8.75 | 8.22 | −5.66 | 13.28 |
| 4 | wood | 63.9 | 7.35 | 18.07 | – | – | – | – |
| | bottom | 41.87 | 9.97 | 36.62 | −22.03 | 2.62 | 18.55 | 28.92 |
| | material | 30.09 | 26.96 | 31.22 | −11.78 | 16.99 | −7.7 | 22.06 |
| 5 | wood | 63.73 | 12.23 | 23.51 | – | – | – | – |
| | bottom | 38.57 | 26.16 | 34.55 | −25.16 | 13.93 | 11.04 | 30.8 |
| | material | 33.3 | 30.97 | 30.29 | −5.27 | 4.81 | −4.26 | 8.31 |
| 6 | wood | 56.96 | 8.97 | 19.03 | – | – | – | – |
| | bottom | 35.27 | 27.8 | 33.08 | −21.69 | 18.84 | 14.06 | 31.98 |
| | material | 29.54 | 34.75 | 27.58 | −5.73 | 6.94 | −15.32 | 17.77 |
| 7 | wood | 50.39 | 14.09 | 23.46 | – | – | – | – |
| | bottom | 30.31 | 30.58 | 26.44 | −20.08 | 16.49 | 2.98 | 26.15 |
| | material | 31.49 | 29.64 | 19.91 | 1.18 | −0.95 | −6.53 | 6.7 |

The first is the effect of the coloring method on the color parameter *L**, that is, the effect on the brightness of the color. The data of the test piece is represented in a chart, and the result is shown in Table 2.

The following information can be seen from Table 2: For specimens 1–6, the $L^*$ parameters show a declining trend from the bottom color modification to the material color modification. The parameter changes of specimen 7 are slightly different, and the value of the $L^*$ parameter in the material color modification area is greater than the bottom color modification. The changes in specimens 1–6 show that for modified poplar wood, the base color modification reduces the brightness of the original wood color, and further material color modification reduces the color brightness again. From the coloring effect, the several steps of coloring are to make the wood obtain the target color. It is the process of color deepening and darkening [22].

The effect of the coloring method on the surface color of the material can be seen more directly by the red–green axis chromaticity parameter $a^*$ and the yellow–blue axis chromaticity parameter $b^*$ (Figures 2 and 3). The larger the positive value of $a^*$, the more reddish the color is. Figure 2 shows that the value of $a^*$ becomes larger after the modified poplar has undergone the bottom color modification operations, indicating that the overall color is more reddish. After the material color modification, the $a^*$ value of the modified poplar wood surface color increased again, indicating that the red dye in the material color modification agent played a role in making the color red.

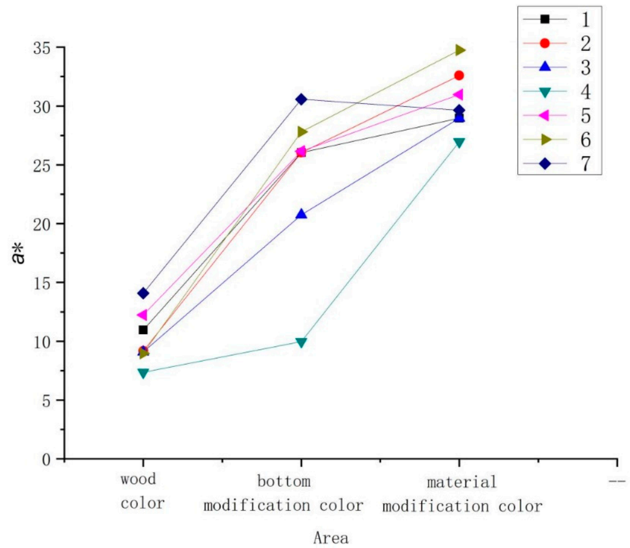


**Figure 2.** The influence of the coloring of specimens in different regions on $a^*$.

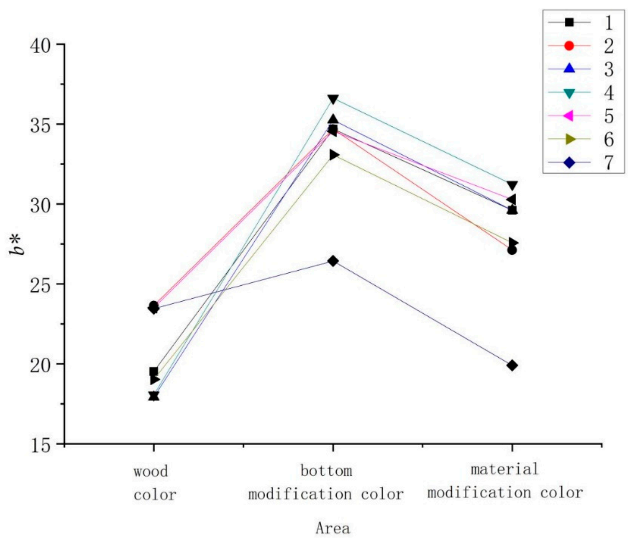


**Figure 3.** The influence of the coloring of specimens in different regions on $b^*$.

The larger the value of $b^*$, the more yellow the surface color is. Figure 3 shows that after the modified poplar wood has undergone the bottom color modification operation, $b^*$ first becomes larger, indicating that the color is yellow, but after the material color modification operation, $b^*$ becomes smaller, indicating that the yellowness of the surface color is weakened. This is due to the 15% coloring dye C.I.Pigment Red 101; 77491 in the Grace used for material color modification covers the yellowish part of the bottom color modification. The effects on modified poplar wood and mahogany wood are consistent.

$C^*$ indicates the degree of color saturation, and Figure 4 shows the color saturation of the specimen. The bottom color modification obviously improves the saturation of the color, while the material color modification has no obvious effect on the further saturation of the color.

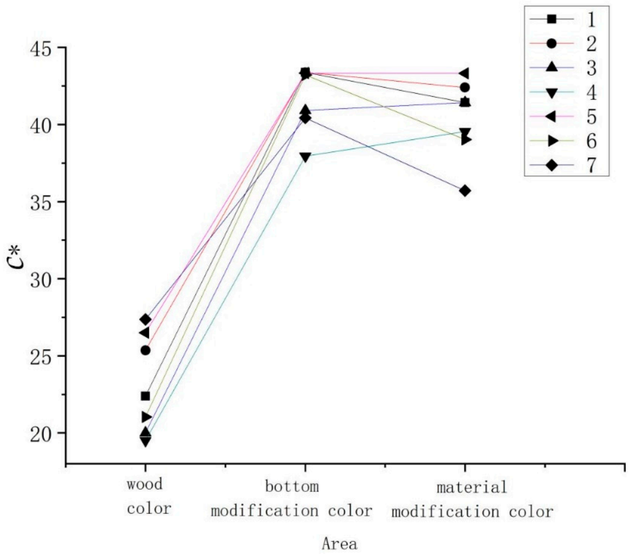


**Figure 4.** Sample color saturation.

Through the above analysis, the bottom color modification makes the surface of the modified poplar wood obtain an obvious reddish and yellowish hue, and the overall color saturation increases, but at the same time, the color brightness decreases. This is because there are yellow and red in the color modification dye. The material color modification deepens the red hue of the modified poplar wood surface, but at the same time weakens the yellow hue, the overall color saturation does not change significantly, and the overall color brightness is reduced. This is caused by the red dye in the Grace stain and other substances that weaken the surface brightness.

### *3.2. The Influence of Different Surface Pretreatments on the Coloring Effect*

Regarding the different surface treatments that were used to modify the poplar in the pretreatment stage, the surface roughness and wettability of modified poplar are also different [23]. The impact of different surface treatments and the different roughness of the surface of the specimen on the coloring effect are the focus of this research. Specimens 2–6 were treated with different types of sandpaper after being painted with a Didebao primer. Therefore, specimens 2–6 were used as the main research objects, specimens 1 and 7 were used as reference specimens.

The first is the influence of different surface pretreatments on the color parameter $L^*$ (Figure 5). In the modified poplar color area, the $L^*$ value showed a trend of first rising and then falling, with a larger downward trend. In the bottom color modification area, the $L^*$ value showed an overall downward trend with a smaller decline. In the material color modification area, $L^*$ changes the least. Taken together, the color brightness values of the three regions show a downward trend as a whole, and the range of changes decreases from wood color and bottom color modification to material color modification. The reason is that as the size of sandpaper increases, the surface roughness of the modified poplar decreases, and the diffuse reflection decreases, resulting in a decrease in the reflected light entering the instrument, so the measured *L** value shows a downward trend. In addition, the two color modification methods both weaken the influence of the color parameter *L**, and the weakening effect of the material color modification operation is greater than the bottom color modification operation.

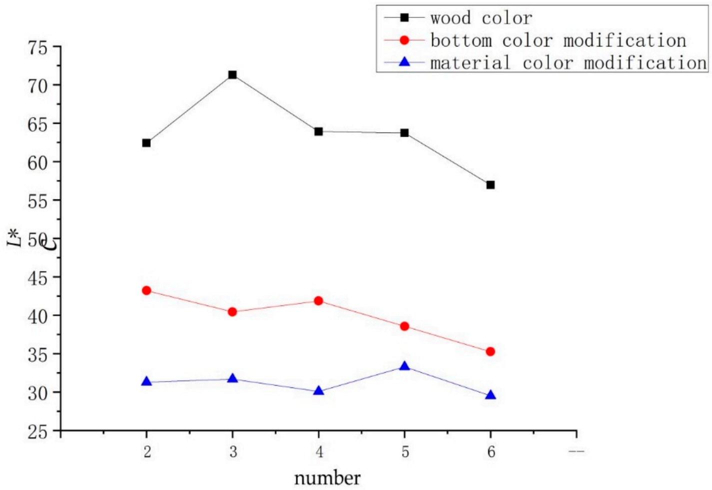


**Figure 5.** The effect of different surface dispositions to *L**.

The influence of different surface pretreatments on *a** value is shown in Figure 6. It can be seen from the figure that there is no obvious regularity in the change of *a** value in the wood color area of the modified poplar, which shows that the red chromaticity value of the modified poplar is not greatly affected by the surface roughness. In the bottom color modification area and the material color modification area, the *a** value shows a trend of first decreasing and then increasing, and reaches the lowest value at specimen 4. This is exactly the same as the average spacing line graph of the microscopic unevenness of the specimens 2–6, the initial and equilibrium contact angle trend graph of distilled water, and the initial and equilibrium contact angle trend graph of glycerol, and they all reach the lowest value at specimen 4, which means that the red–green product parameter *a** in the color is negatively correlated with the compactness and surface wettability in the surface roughness, regardless of the material color modification or the bottom color modification, that is, the denser the surface of poplar wood, the greater the wetting ability, the weaker the ability of the material or the bottom color modification to make the surface red [23].

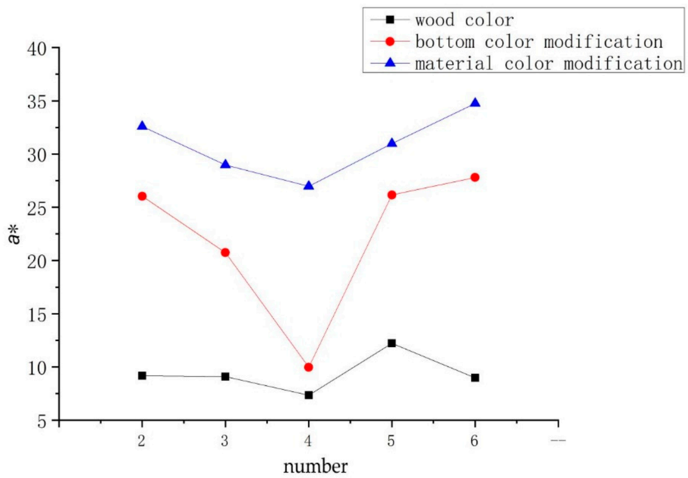


**Figure 6.** The effect of different surface disposition to *a**.

The influence of different surface pretreatments on the $b^*$ value is shown in Figure 7. It can be seen from the figure that in the wood color area, there is no obvious regularity in the change of $b^*$ value. The yellowishness of the modified poplar wood color is greatly affected by the material's own performance [24]. In the material and the bottom color modification area, the $b^*$ value shows a trend of first increasing and then decreasing, which is the opposite of the change trend of $a^*$, and the change trend of the average distance between the surface unevenness of the material and the initial and equilibrium contact angles of distilled water and glycerol. On the contrary, this indicates that the yellow–blue product parameter $b^*$ in the job color is positively correlated with the compactness and surface wettability in the surface roughness, regardless of the bottom color modification or the material color modification [25]. That is to say, when the density of the modified poplar wood surface is greater and the wettability is stronger, the yellowishness of the material color correction and background color correction work effect is more obvious [26].

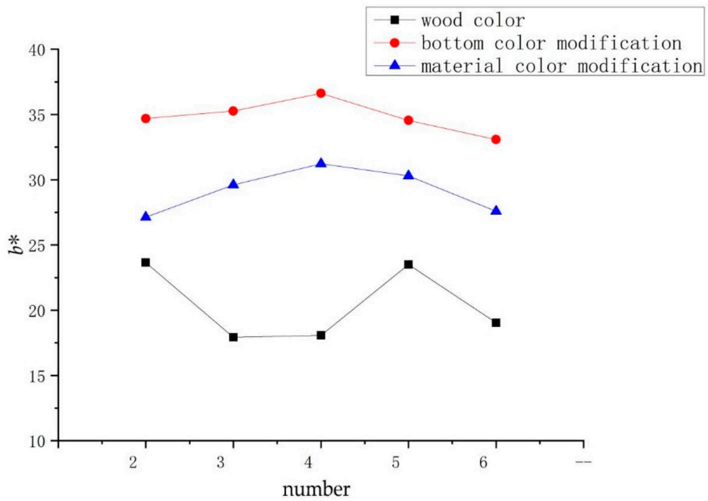


**Figure 7.** The effect of different surface disposition to $b^*$.

The color saturation parameter $C^*$ is the comprehensive effect of $a^*$ and $b^*$ values, as shown in Figure 8. It can be seen from the figure that the change in trend of the $C^*$ value in the bottom color modification area is similar to the $a^*$ value, which is due to the large change of $a^*$. In the material color modification area, the $C^*$ value changes not significantly, because the $a^*$ and $b^*$ values are close to each other. The material of specimen 7 is mahogany. As a reference test piece, it is treated in the same way as that of specimen 5 in the pretreatment stage. As shown in Figures 2–4, you can see the following points by comparison: the difference of the value of lightness $L^*$ in the wood color area is 13.34, in the bottom modification area is 8.326 and in the material modification area is 1.81, showing a gradual decrease. The small trend indicates that continuous coloring can reduce the lightness gap between modified poplar and the mahogany coloring layer. The difference of a* value in the wood color area is 1.86, in the bottom modification color area it is 4.42 and in the material color modification area it is 1.33, showing a trend of increasing first and then decreasing. This shows that although the bottom color modification makes the red color value difference of the two woods larger, the material color correction operation has narrowed the gap, and it is smaller than the difference in the modified poplar's own material color. The $b^*$ value is 0.05 in the wood color area, 8.11 in the bottom color modification area, and 10.38 in the material color modification area, showing an increasing trend. It shows that the colorant of the walnut paint film will increase the yellow–blue color difference between the modified poplar and mahogany during the continuous coloring. The change in the difference in color saturation is affected by the $b^*$ value with a large change range, and this also shows a gradually increasing trend [27].

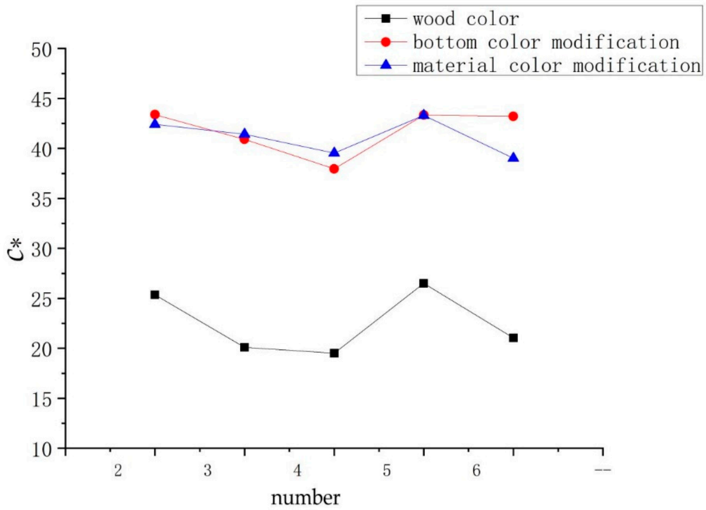


**Figure 8.** The effect of different surface disposition to *C**.

In summary, it can be seen that the colorant and coloring steps will have an impact on the color difference between modified poplar and mahogany. The colorant in this experiment is a reddish dye. The accumulation of color can reduce the difference in brightness and the red–green axis chromaticity index; that is to say, the coloring process can narrow the coloring effect of modified poplar and mahogany.

## 4. Conclusions

The bottom color modification makes remodeling the green product index *a**, yellow color product index *b**, color harmony *C** increase, color lightness L* decrease; green color product index *a** increase, yellow color product index *b** small, manipulative color harmony *C** eccentric change, and dark color manipulative lightness *L** decrease. After coloring, the surface brightness *L** is weakened and the material color modification weakening effect is larger than the bottom color modification. Continuous coloring can reduce the brightness gap in the coloring layer of modified poplar and mahogany. The bottom color modification will make the red color value of the two types of wood larger, but the material color modification has narrowed the gap. Therefore, the coloring agent and the coloring step will affect the coloring difference between the modified poplar and the common wood. Through the color accumulation, the gap between the two colors can be reduced, thereby reducing the coloring effect of the modified poplar and the common wood.

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## References

1. Yan, X.X. Effect of different color paste on properties of fluorine resin/aluminum infrared low emissivity coating. *Coatings* **2020**, *10*, 70. [CrossRef]
2. Yan, X.X.; Chang, Y.J.; Qian, X.Y. Effect of concentration of thermochromic ink on performance of waterborne finish films for the surface of cunninghamia lanceolata. *Polymers* **2020**, *12*, 552. [CrossRef]

3. Cakicier, N.; Korkut, S.; Korkut, D.S. Varnish nayer hardness, scratch resistance, and golssiness of various wood species as affected by heat treatment. *Bioresources* **2011**, *6*, 1648–1658.
4. Yan, X.X.; Han, Y.; Yin, T.Y. Synthesis of urea-formaldehyde microcapsule containing fluororesin and its effect on performances of waterborne coatings on wood surface. *Polymers* **2021**, *13*, 1674. [CrossRef]
5. Yan, X.X.; Zhao, W.T.; Qian, X.Y. Effect of water-based emulsion core microcapsules on aging resistance and self-repairing properties of water-based coatings on Linden. *Appl. Sci.* **2021**, *11*, 4662. [CrossRef]
6. Yan, X.X.; Peng, W.W. Effect of microcapsules of a waterborne core material on the properties of a waterborne primer coating on a wooden surface. *Coatings* **2021**, *11*, 657.
7. Salca, E.A.; Krystofiak, T.; Lis, B.; Mazela, B.; Proszyk, S. Some coating properties of Black Alder Wood as a function of varnish type and application method. *Bioresources* **2016**, *11*, 7580–7594. [CrossRef]
8. Paula, M.H.; Mesquita, R.R.S.; Costa, M.D.; Goncalez, J.C.; Ananias, R.A.; Janin, G. Effect of applying finishing products and sanding on the surface of marupa wood. *Maderas. Ciencia y Tecnología* **2020**, *22*, 45–54. [CrossRef]
9. Meijer, M.; Thurich, K.; Militz, H. Comparative study on penetration characteristics of modern wood coatings. *Wood Sci. Technol.* **1998**, *32*, 347–365. [CrossRef]
10. Moura, L.F.; Brito, J.O.; Nolasco, A.M.; Uliana, L.R.; De Muniz, G.I.B. Evaluation of coating performance and color stability on thermally rectified eucalyptus grandis and pinus caribaea war. *Wood Res.* **2013**, *5*, 231–242.
11. Hernandez, R.E.; Cool, J. Evaluation of three surfacing methods on paper birch wood in relation to water- and solvent-borne coating performance. *Wood Fiber Sci.* **2008**, *40*, 459–469.
12. Pelit, H.; Budakci, M.; Sonmez, A.; Burdurlu, E. Surface roughness and brightness of scots pine (*Pinus sylvestris*) applied with water-based varnish after densification and heat treatment. *J. Wood Sci.* **2015**, *61*, 586–594. [CrossRef]
13. Aksoy, A.; Deveci, M.; Baysal, E.; Toker, H. Colour and gloss changes of socts pine after heat modification. *Wood Res.* **2011**, *56*, 329–336.
14. Yan, X.X.; Wang, L.; Qian, X.Y. Effect of coating process on performance of reversible thermochromic waterborne coatings for Chinese Fir. *Coatings* **2020**, *10*, 223. [CrossRef]
15. Goncalez, J.C.; Felix, T.L.F.; Gouveia, F.N.; Camargos, J.A.A.; Ribeiro, P.G. Effect of ultraviolet radiation on the color of freijo wood (Cordia goeldiana Huber) after application of finishing products. *Ciência Florest.* **2010**, *20*, 657–664.
16. Imirzi, H.O.; Ulker, O.; Burdurlu, E. Effect of densification temperature and some surfacing techniques on the surface roughness of densified scots pine (*Pinus sylvestris* L.). *Bioresources* **2014**, *9*, 191–209. [CrossRef]
17. Demirci, Z.; Sonmez, A.; Budakci, M. Effect of thermal ageing on the gloss and the adhesion strength of the wood varnish layers. *Bioresources* **2013**, *8*, 1852–1867. [CrossRef]
18. Nejad, M.; Shafaghi, R.; Ali, H.; Cooper, P. Coating performance on oil-heat treated wood for flooring. *Bioresources* **2013**, *8*, 1881–1892. [CrossRef]
19. Baysal, E.; Tomak, E.D.; Ozbey, M.; Altin, E. Surface properties of impregnated and varnished scots pine wood after accelerated weathering. *Color Technol.* **2014**, *130*, 140–146. [CrossRef]
20. Gong, M.; Lamason, C.; Li, L. Interactive effect of surface densification and post-heat-treatment on aspen wood. *J. Mater. Process. Technol.* **2010**, *210*, 293–296. [CrossRef]
21. Korkut, D.S.; Korkut, S.; Bekar, I.; Budakci, M.; Dilik, T.; Cakicier, N. The effects of heat treatment on the physical properties and surface roughness of Turkish Hazel (*Corylus colurna* L.) wood. *Int. J. Mol. Sci.* **2008**, *9*, 1772–1783. [CrossRef] [PubMed]
22. Mendes, T.J.; Gonalez, J.C.; Teles, R.F.; Lima, C.M. Effect of artificial weathering on wood laminates color treated with two finishing products. *Cerne* **2016**, *22*, 101–109. [CrossRef]
23. Liu, Q.Q.; Gao, D.; Xu, W. Effect of sanding processes on the surface properties of modified poplar coated by primer compared with mahogany. *Coatings* **2020**, *10*, 856. [CrossRef]
24. Yan, X.X.; Zhao, W.T.; Qian, X.Y. Effect of urea-formaldehyde (UF) with waterborne emulsion microcapsules on properties of waterborne acrylic coatings based on coating process for American Lime. *Appl. Sci.* **2020**, *10*, 6341. [CrossRef]
25. Wang, L.; Yan, X.X. Mechanical and optical properties of thermochromic reversible waterborne primer film on *Tilia europaea* with 1,2-benzo-6-diethylaminofluorane based microcapsules. *Polymers* **2020**, *12*, 2062. [CrossRef] [PubMed]
26. Yan, X.X.; Qian, X.Y.; Lu, R.; Miyakoshi, T. Comparison and optimization of reactive dyes and coating performance on *Fraxinus mandshurica* veneer. *Polymers* **2018**, *10*, 1302. [CrossRef]
27. Yan, X.X.; Tao, Y.; Qian, X.Y. Preparation and optimization of waterborne acrylic core microcapsules for waterborne wood coatings and comparison with epoxy resin core. *Polymers* **2020**, *12*, 2366. [CrossRef] [PubMed]