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Research Article

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Performance of Finish on The Wood Surface Treated by Rosin-Copper Solutions

Thi Thanh Hien Nguyen[1,*] , Nho Cuong Tran[1]

[1]Vietnam National University of Forestry, Ha Noi, Viet Nam.
*Corresponding author: Email: hiencblsvfu@gmail.com Tel/Fax: +84-432-232054/+84-433-840 063

Abstract Wood modification is commonly used to alter and improve wood properties. In this study, the mixture of 1%, 2%, or 4% rosin sizing agent solution and 3% copper sulfate was used to impregnate Acacia hybrid (*Acacia mangium x auriculiformis*) wood and then were coated with Polyurethane (PU). The effects of rosin-copper modified treatment on some surface finishing properties such as dry film thickness, dry rate, color change, glossiness, and adhesion strength on the treated wood surface after coating were also studied. The result showed: Using the rosin sizing agent alone or in combination with copper sulfate to impregnate Acacia hybrid wood did not affect the drying rate of the finish, dry film thickness, glossiness, and the adhesion of the paint film. After being treated with rosin-copper formulations, the surface of the wood was slightly darker compared to untreated wood but did not affect the color of the paint film on the treated wood surface. Moreover, the concentration of the rosin sizing agent used in this study did not significantly affect the drying rate of the finish, dry film thickness, glossiness, adhesion, and color discoloration of the paint film. The use of rosin-copper formulations to treat wood could not only reduce the damage of the copper preservative leaching into the environment but also did not affect the quality of the paint film on the treated wood surface.

Keywords Adhesion strength, dry film thickness, color change, glossiness, drying rate

1. Introduction

Wood has been used extensively in outdoor and indoor applications due to its abundance and versatility such as being easy to process, having a good sound, heat insulation, and being friendly to humans and the environment. However, wood also has been easily damaged by fungi and insects, especially wood is very susceptible to warping, cracking, and dimensional instability when used in outdoor conditions. Wood materials can be protected against these factors by applying the wood treatment process and/or wood finishing.

The first option is using wood preservatives. Rosin is a natural product, it has very good hydrophobicity and is friendly to humans, thus it has been widely used in the paper industry as a sizing agent [1]. In addition, Rosin has also been used alone or in combination with copper/boron to impregnate wood and the results have shown that rosin also could improve wood decay resistance [2-5]. The second option is applying coatings. A variety of finishes or coatings can be applied to wood. However, the surface coating of wood is one of the most important parameters influencing the properties of wood products. Ozdemir et al. (2015) [6] showed that: preservative compounds such as CCA, Tanalith E, boric acid, and Immersol aqua did not affect the scratch resistance but significantly increase the abrasion resistance of the paint film on the surface of pine, oak, and chestnut wood; Toker et al. (2009) [7] reported that pine wood treated with borate compounds before varnishing increased the hardness and gloss of the coating film, but reduced the adhesion of coating film. Yalinkilic et al. (1999) [8]

reported that Scotland pine and chestnut wood treated with chromium-copper-boron (CCB), followed by coating with polyurethane varnish or alkyd-based synthetic varnish increased color stability of the wood surface, reducing the weight loss of the wood and can protect the wood in outdoor conditions for a long time. However, there are no reports on the effect of rosin-copper on the quality of coating film on the treated acacia hybrid wood surface. Therefore, this work was aimed at evaluating the effect of treatment by rosin-copper formulations on the performance of PU coating on acacia wood surfaces.

2. Materials and Methods

2.1. Treating wood blocks

Acacia hybrid (*Acacia mangium x auriculiformis*) wood was selected according to the TCVN 8044: 2014 (same ISO 3129:2012) [9] standard. Wood specimens were cut from untreated Acacia hybrid wood into blocks with dimensions of 150 × 50 × 15 mm. Deficiency-free specimens were selected for the tests.

Before the treatment, all wood blocks were oven-dried at 60 ± 2ºC to constant weight and weighed (W_1). The blocks were then impregnated with aqueous solutions of 1%, 2%, or 4% rosin sizing agent (was purchased at Guangxi Wuzhou Arakawa Chemical Industries Co., Ltd) plus 3% copper sulfate (was provided by Tianjin Kermel Chemical Reagent Co., Ltd) using a full-cell pressure process at 0.1 MPa vacuum for 60 min followed by 0.6 MPa pressure for 60 min. Then the blocks were kept in the treatment solution for 60 min under atmospheric conditions. The blocks were then individually removed from the solution, wiped lightly to remove the solution from the wood surface, and immediately weighed to determine the mass after impregnation (W_2). The retention of each block was calculated according to the following formula:

$$\text{Retention, kg/m}^3 = \frac{GC}{V} \times 10 \quad (1)$$

where $G = W_2 - W_1$ is the weight in grams of the treating solution absorbed by the block, C is the weight (g) of preservative in 100 grams of treating solution, and V is the volume of the block in cubic centimeters.

After the treatment process, all wood blocks were stored at ambient laboratory temperature for air drying and fixation for 4 weeks.

2.2. Surface coating process

All untreated control and treated samples were coated with two-component PU paint (including 612G primer with 56% dry content and 2099 code gloss paint with dry content 52%) and PU hardener code number OL17 using the pneumatic spray method. All paint systems were obtained from the Oseven company. The painting process is carried out as follows: First, the surface of wood samples is sanded, then primed for the first time. Next, the samples are air-dried, sanded, and primed for the second time. When the paint film was dry, the wood sample is further sanded and polished for the last time. After polishing, the wood samples are placed at ambient laboratory temperature for about 1 month to let the paint film dry naturally and stably.

2.3. Dry film thickness

The dry coating thickness of samples treated with wood preservatives and untreated (control) was determined according to the TCVN 9760: 2013 (same ISO 2808: 2007) [10].

2.4. Adhesion strength

Adhesion strength based on the cross-hatch cutter method was determined according to DIN EN ISO 2409 [11]. The scale for evaluating the adhesion runs from 0 to 5. A value of 0 stands for perfect adhesion, whereas a value of 5 represents the complete flaking of the paint.

2.5. Gloss measurement

Gloss measurement was carried out according to the standard test of ASTM D523-14 by using a Gloss checker (HORIBA IG-320, HORIBA. Ltd., Japan). The chosen geometry was from an incidence angle of 60°. Results were based on a specular gloss value of 91, which related to the perfect condition under identical illumination and viewing conditions of a highly polished, plane, and black glass surface. Gloss measurements were made parallel to the fibers.

2.6. Color measurement

Color measurements were performed on the wood surfaces before and after coating by using an NF–333 Spectrophotometer (Nippon Denshoku Industries Co. Ltd., Tokyo, Japan) with a standard measuring aperture of 4 mm diameter. The CIELAB system is characterized by three parameters, lightness (L*) and color coordinates (a* and b*) (Fig. 1). The color change, ΔE* after coating, was calculated according to Eq. 2.

$$\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad (2)$$

where ΔL*, Δa*, and Δb* are the changes between the initial (i) and final (f) values. Ten replicates were made for each treatment group.

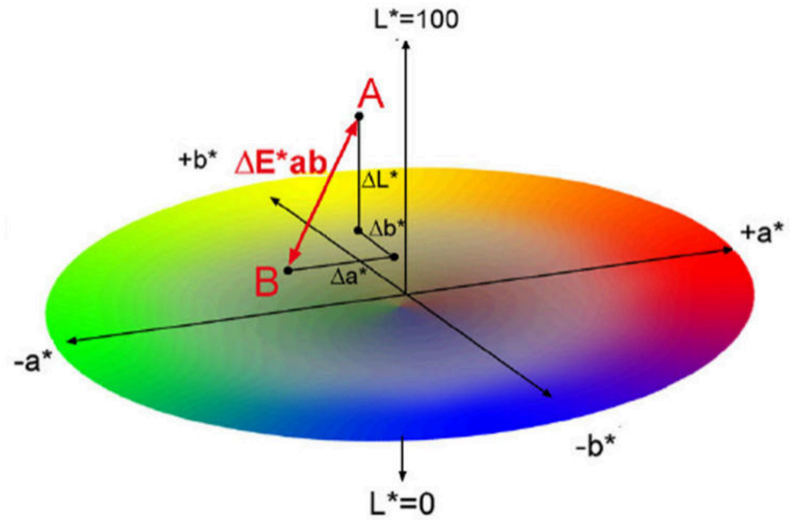

Figure 1: The CIELAB color space [12]

2.7. Drying rate of paint

Drying rates of paint were determined according to what was described by Ekstedt (2003) [13]. A swatch of cotton wool was dropped on the coated wood surface from a height of 5 cm; afterward, the coated sample was turned upside down to determine whether the cotton had stuck to the coating film. The time at which the cotton ceased to stick to the film was defined as the final surface-drying time of the wood finish. To determine the time required for complete drying (through drying), a cotton swab was placed on the coating film and subjected to a weight of 1 kg for 10 s. Through-drying time was recorded as the time at which no remaining cotton was found adhering to the film after removal of the cotton swab.

2.8. Statistical Analysis

To compare the results obtained from experiments, the one-way ANOVA and homogeneous groups were used to compare mean values of variance sources by using SPSS 25.0 statistical software package.

3. Results and Discussion

3.1. Drying Rate of Paint on Wood

The surface-drying time and through-drying time of paint on all untreated and treated wood are shown in Figure 2. The drying process of finishing on the surface of the wood is characterized by various stages. These include the penetration of the solvent into the wood cells and the volatilization of the solvent in air, the flocculation and rearrangement of the solute, the packing of the pigment particles (if existent), and finally, the hardening. Thus, the drying rate of finishes depends not only on the types of paints but also on the substrates [14]. The surface-drying and through-drying times of PU paint on the untreated control were 0.36h and 1.49h, while for all treated samples were 0.37 – 0.39h and 1.49 - 1.50h, respectively. These results showed that Acacia hybrid wood treated with rosin sizing agents alone or in combination with copper sulfate did not change the drying rate of the finish when compared to those of the untreated wood substrate. There was no notable difference in the drying rate of the finish when the concentration of the rosin sizing agent increased from 1% to 4% in the impregnating solution.

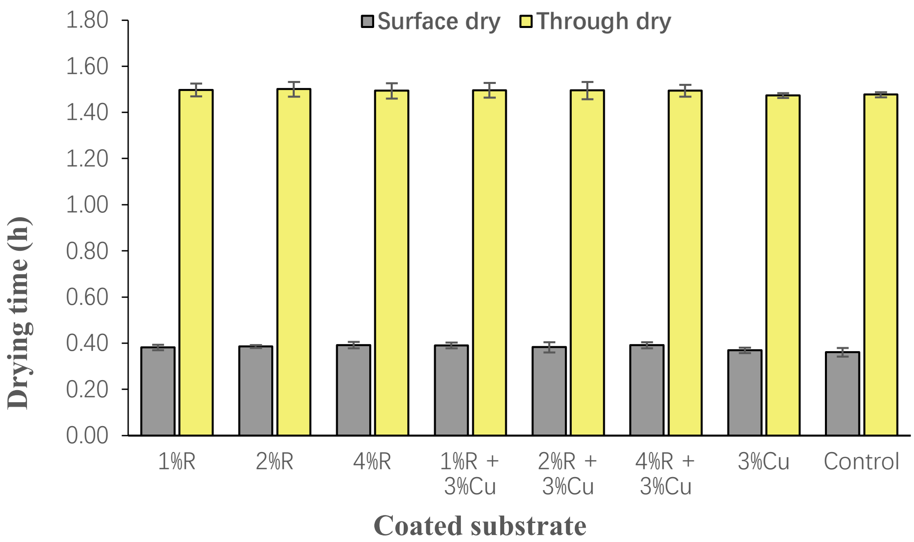

Figure 2: Drying time of coating film on wood surface treated with rosin-copper

3.2. Dry film thickness

The dry film thickness of treated and untreated wood was found in Table 1. According to Table 1, the dry film thickness of the untreated wood sample was found as 45.53μm, while the treated wood samples ranged from 45.25 to 45.84μm. This result indicated that the wood treated with rosin-copper formulations did not affect the dry film thickness of the paint. The results of ANOVA analysis also showed that no differences were found between untreated and treated wood samples. These results agreed with those obtained by Ozdemir et al. (2015) [6].

Table 1: Dry film thickness and gloss values of acacia hybrid wood surface treated with rosin-copper solutions

Concentrations	Retention (Kg/m^3)	Film dry thickness (μm)	Glossiness
1.0%R	3.55 (1.30)	45.50^a	78.73 (7.81)^a
2.0%R	6,31 (1.79)	45.55^a	81.18 (5.58)^a
4.0%R	11,63 (3.36)	45.65^a	83.62 (3.73)^a
1.0%R + 3.0%Cu	11,15 (1.82)	45.25^a	78.46 (5.93)^b
2.0%R + 3.0%Cu	15,27 (3.03)	45.25^a	79.52 (5.32)^a
4.0%R + 3.0%Cu	21,15 (2.59)	45.71^a	80.46 (6.15)^a
3.0%Cu	8,01 (0.70)	45.84^a	79.78 (5.51)^a
Control	-	45.53^a	83.67 (6.16)^a

Note: Standard deviations are in brackets; Cu: anhydrous copper sulfate and R: rosin sizing agent; Means within a column followed by the same letter are not significantly different at 5% level of significance using the one-way ANOVA test

3.3. Glossiness results

Table 1 illustrate the effect of rosin-copper treatment on gloss values of the paint film on the wood surface. The result showed that impregnation treated wood before the coating has slightly reduced the gloss values. The average gloss value of the paint film on the untreated wood surface before painting is 83.67, while wood samples are impregnated with rosin sizing agents alone or in combination with copper sulfate were in the range of 78.46 – 83.62. This can be explained as follows: When the wood is treated with wood preservatives before painting, it will increase the surface porosity and raised fibres, thereby reducing the gloss value of the paint film [6]. When the concentration of rosin sizing agent in the impregnation solution increases from 1% to 4%, the gloss of the paint film tends to increase slightly. However, the results of the ANOVA analysis showed that there was no significant difference in the gloss of paint film on wood surfaces treated with rosin sizing agent alone or in combination with copper sulfate compared with the untreated controls and no significant differences were found when the concentration of rosin sizing agent changed.

3.4. Adhesion results

The results of testing the adhesion of the paint film on the wood surface treated by the rosin-copper formulations are shown in Figure 3.

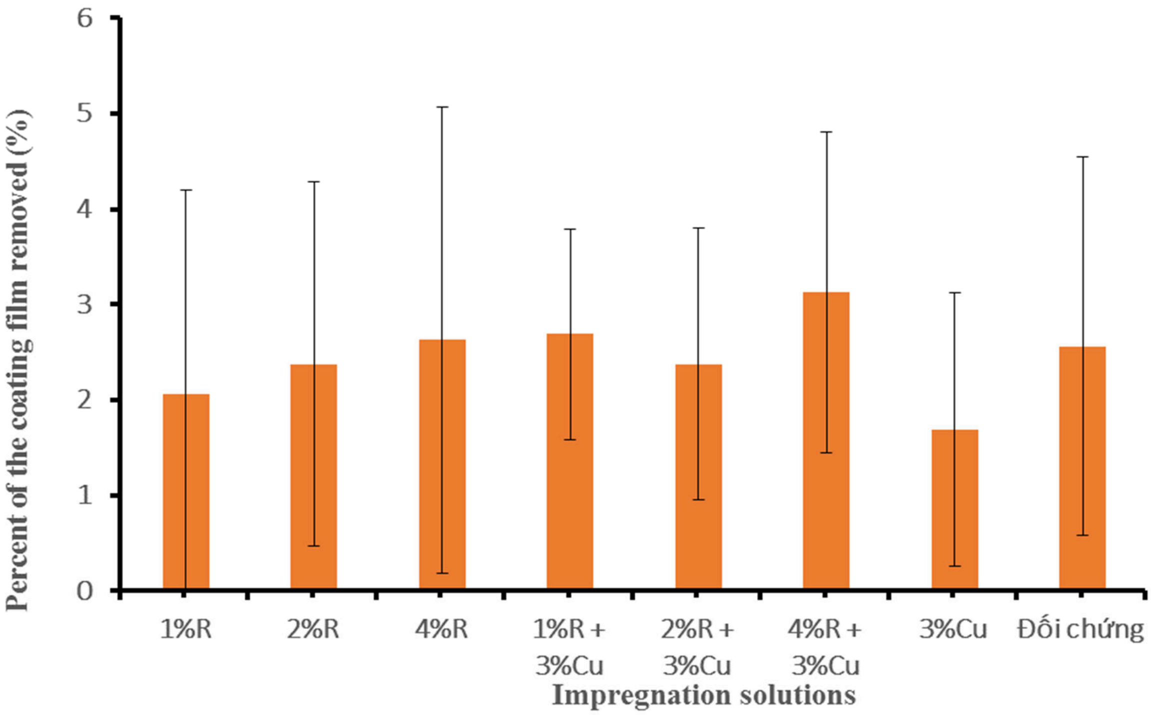

Figure 3: Adhesion of coating film on Styrax wood treated with rosin-copper solutions

The results showed that the adhesion of the PU coating film on the wood surface treated with rosin sizing agents or copper sulfate alone was slightly higher than untreated control and rosin-copper treated samples. However, the total cross-cut area being flaked of both untreated and treated samples is less than 5%, corresponding to the adhesion of the paint film reaching level 1. When the concentration of rosin sizing agent increased, the adhesion of the paint film tended to decrease. This could be related to poor wetting properties after impregnation with a higher concentration of rosin sizing agent. The fact that the poor wettability resulted in poor adhesion was also observed by Shupe et al. [15], and Maldas and Kamdem [16]. However, the reduction was not significant. These results indicated that the Acaia hybrid wood after being treated with the mixture of rosin sizing agents and copper sulfate did not affect the adhesion of the paint film on the wood surface compared to untreated controls. This result is similar to the studies of Bardage and Bjurman (1998) [17] or Ozdemir and Hiziroglu (2007) [18].

3.5. Color variation

The result of the change in values of three-color parameters (ΔL*, Δa*, and Δb*) and the total color change (ΔE*) of Acacia hybrid wood surface treated with rosin-copper after coating are shown in Table 2. Before coating, the L*, a*, and b* values of the untreated controls were 65.32, 9.39, and 20.14, respectively. For the wood samples only impregnated with rosin sizing agents, L* values ranged from 65.63 to 68.36; a* values ranged from 8.78 to 9.41, and b* values from 20.05 to 20.98. However, after combination with copper sulfate, L* and a* values slightly decreased only ranging from 60.58 to 65.04, and from 8.22 to 8.74, respectively. This result showed that Acacia hybrid wood is slightly brown, reddish, and yellowish (Figure 4). After being treated with rosin sizing agents only, the wood surface did not be changed much compared to the untreated sample, however, after combining with copper sulfate, the treated wood surface turned greener and slightly darker compared with other wood samples. This result was due to the presence of copper in the impregnation solution, which contribute to the darkening.

Table 2: Color change of Acacia hybrid wood treated with rosin-copper solutions after coating

Solutions and Concentrations	**Before coating**			**After coating**			
	L*	**a***	**b***	**ΔL***	**Δa***	**Δb***	**ΔE***
1%R	68.36 (4.58)	8.78 (0.68)	20.98 (2.99)	-3.58 (2.19)	2.40 (1.28)	4.01 (1.68)	6.13 (2.44)[a]
2%R	65.63 (4.1))	9.41 (0.8)	20.26 (1.46)	-5.52 (2.42)	3.39 (0.83)	4.19 (1.13)	8.44 (1.94)[a]
4%R	66.24 (3.59)	9.01 (0.93)	20.05 (1.24)	-6.36 (3.57)	2.98 (1.01)	4.06 (1.69)	8.72 (2.79)[a]
1%R+ 3% Cu	60.58 (7.33)	8.37 (0.87)	19.00 (2.86)	-6.94 (2.17)	2.00 (1.16)	2.87 (1.27)	8.02 (2.57)[a]
2%R+ 3% Cu	62.62 (4.89)	8.74 (1.04)	20.51 (2.37)	-7.66 (2.31)	2.56 (1.20)	2.61 (1.30)	9.10 (2.33)[a]
4%R+ 3% Cu	65.04 (8.40)	8.22 (0.8)	19.88 (2.64)	-6.11 (2.41)	2.77 (1.25)	4.07 (1.25)	8.52 (2.32)[a]
3% Cu	64.65 (3.64)	9.05 (0.85)	20.34 (1.19)	-6.72 (2.23)	2.19 (0.82)	3.54 (1.37)	8.98 (2.40)[a]
Control	65.32 (5.83)	9.39 (1.09)	20.14 (1.22)	-7.13 (2.69)	2.80 (1.32)	3.04 (1.52)	8.71 (2.10)[a]

Note: Standard deviations are in brackets; Cu: anhydrous copper sulfate and R: rosin sizing agent; Means within a column followed by the same letter are not significantly different at 5% level of significance using the one-way ANOVA test.

After being coated with PU, the values of Δa* and Δb* were positive in all untreated control and treated samples. This shows that the surface of Acacia hybrid wood becomes redder-yellow after coating. Brightness stability (ΔL*) is considered to be the most sensitive parameter of wood surface quality [19]. In this study, the ΔL* value was found to be negative for all treated and untreated samples, indicating that the wood surface became darker after coating. The total color change (ΔE*) of untreated controls was 8.71, while the samples treated with rosin sizing agents solution alone or in combination with copper sulfate ranged from 6.13 to 9.10. The results showed that there are only minor differences in ΔE* between untreated control and rosin-copper treated samples and when the concentration of rosin sizing agent in the mixture increased from 1% to 4%, the total color change also only increased slightly. It is assumed that the reflection of light on the coated wood surface is due to the absorption of light by the finish, which is caused mainly by the pigments and the binders [20]. Which would explain why only minor differences in color variation between treated and untreated wood were detected. Furthermore, the results of ANOVA analysis (Table 2) also showed there was no significant difference in the color variation of all treated wood samples compared with the untreated control, and there was no obvious difference when the concentration of the rosin sizing agent increased from 1% to 4%. This result confirmed that using rosin sizing agents alone or in combination with copper sulfate to treat wood did not affect the color of the paint film on the treated wood surface.

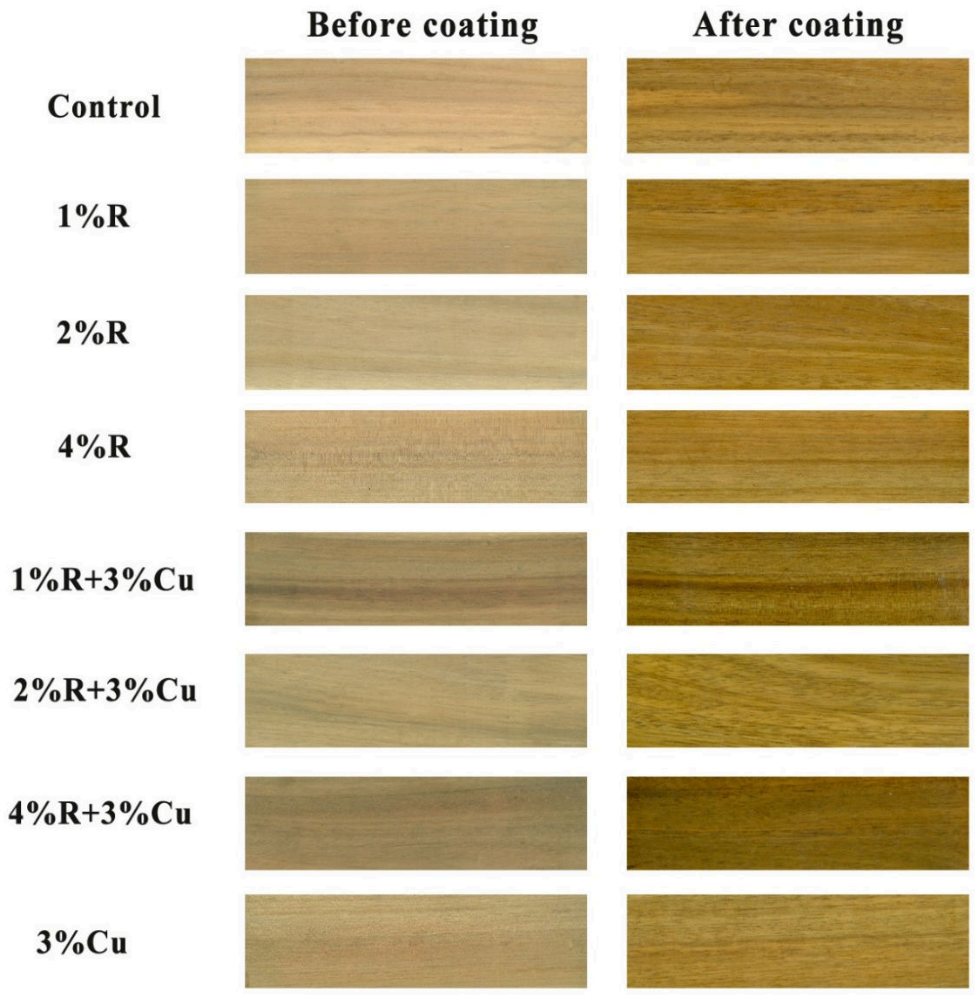

Figure 4: *The appearance of untreated control and treated samples before and after coating*

(Cu: anhydrous copper sulfate and R: rosin sizing agent)

4. Conclusions

This study dealt with the effect of wood preservatives on the performance of finishing. The mixtures of 1%, 2%, or 4% rosin sizing agent solution and 3% copper sulfate were used to impregnate Acacia hybrid wood and then were coated with Polyurethane. Some surface finishing properties were tested. The results showed that using a combination of rosin sizing agents and copper sulfate to impregnate Acacia hybrid wood did not affect the drying rate of the finish, dry film thickness, glossiness, and the adhesion of the paint film. Moreover, the concentration of the rosin sizing agent used in this study did not affect the drying rate of the finish, dry film thickness, glossiness, and the adhesion of the paint film.

After being treated with rosin-copper formulations, the surface of the wood was slightly darker compared to untreated wood but also did not affect the color of the paint film on the treated wood surface. The concentration of rosin sizing agents used in this study did not significantly affect the color discoloration of the paint film.

Using the rosin sizing agents in combination with copper sulfate to impregnate Acacia hybrid wood could not only reduce the damage of the copper preservative leaching into the environment but also did not affect the quality of the paint film on the treated wood surface.

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