Coating Performance Enhancement of Moso Bamboo (*Phyllostachys edulis*) *via* Hand Sanding: Effects of Surface Dewaxing and Fibrillation

Yong-Hui Choi,[a] Byeongho Kim,[a] Ji-Yeon Sim,[a] Kyoung-Jung Kim,[b] and Se-Yeong Park [a,*]

Bamboo, despite its environmental advantages, often suffers from poor coating adhesion because of its natural surface characteristics, thereby limiting its application as an exterior material. This study aimed to improve the performance of coatings applied to moso bamboo (*Phyllostachys edulis*) by introducing surface sanding as a pretreatment. Sanding was performed using #100 sandpaper with stroke counts of 10, 20, 30, and 40; the resulting changes in the epidermal and fibrous layers and their influence on the coating adhesion were evaluated. The 40-stroke treatment exposed the fibrous layer and enhanced the surface wettability. According to the ISO 2409 (2020) cross-cut test, the sanded specimens exhibited excellent adhesion (Grade 1), in contrast to untreated specimens, for which coating delamination was evident. Furthermore, under accelerated-aging tests, coating adhesion was maintained for the sanded samples, whereas pronounced delamination was observed for the untreated samples. These findings demonstrated the effectiveness of surface sanding. In conclusion, surface pretreatment is essential for improving the durability and coating quality of moso bamboo, and the results of this study can serve as fundamental data for the practical application and broader utilization of bamboo materials.

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Keywords: Moso bamboo; Surface sanding; Surface coating; Coating adhesion test; Dewaxing and fibrillation

Contact information: a: Department of Forest Biomaterials Engineering, College of Forest Environmental Sciences, Kangwon National University, Chuncheon 24341, Republic of Korea; b: Heat treatment Co., Ltd. Daejeon, 34134, Republic of Korea;
** Corresponding author: parksy319@kangwon.ac.kr*

INTRODUCTION

Bamboo, which grows rapidly, has been referred to as the “green gold” of the plant kingdom and has attracted attention as a representative ecofriendly resource that symbolizes low-carbon and sustainable development. Despite its low weight, bamboo has high strength and durability. Moreover, it exhibits high tensile strength owing to its fibrous structure (Lou *et al.* 2023). Thus, bamboo is an ideal material for various applications, such as textiles, furniture, and building materials. Among the various bamboo species, moso bamboo (*Phyllostachys edulis*) is one of the most widely cultivated and economically important species in East Asia, particularly in South Korea, China, and Japan. Its large size, fast growth, and excellent mechanical properties make it a preferred material for structural and decorative applications. However, bamboo is sensitive to climate and environmental changes, and long-term exposure to the external environment causes various deterioration phenomena, including color changes, cracks, and biological damage. Such phenomena reduce the mechanical strength and dimensional stability of the bamboo, and this disadvantage is a major constraint for the application of bamboo to external structures or facilities (Chen *et al.* 2021; Gao *et al.* 2025). Therefore, appropriate surface protection technologies are essential to enable the use of bamboo as a material for external facilities.

At present, surface coating is regarded as the most effective surface treatment method for ensuring durability and maintaining aesthetics. In general, such coatings prevent degradation, improve appearance, and extend the material lifespan.

Depending on the intended use, coatings range from opaque paints suitable for outdoor exposure, which provide good resistance to ultraviolet (UV) radiation, to transparent or semi-transparent varnishes used for aesthetic purposes. High coating performance can be achieved when the appropriate series of processes—from surface pretreatment to the application and hardening of coating materials—are properly performed (Stojanović *et al.* 2023). Additionally, the coating efficacy is significantly affected by the surface characteristics of the target material.

In contrast to wood, bamboo has a hollow, thin-walled structure, and its surface comprises complex layers that directly affect the coating process. The outermost layer (0 to 25 μm thick)—a hydrophobic natural wax layer composed of alkanes, alcohols, ketones, terpenoids, and esters—prevents the infiltration of moisture and chemicals. Fiber cells are distributed within the internal layers (40 to 50 μm thick). In one layer, silicon components are mainly deposited. Toward the center, vascular tissues comprising parenchyma cells, phloem, and xylem are found (He *et al.* 2022). The hydrophobic wax layer protects the bamboo from external deterioration factors; however, it also prevents coating materials and adhesives from penetrating the surface by reducing the surface wettability. This reduction in wettability caused by the wax layer may negatively impact the coating-layer adhesion and durability. Indeed, Lu (2006) reported that the surface wax layer degrades coating adhesion and causes delamination by hindering coating-material penetration. Therefore, appropriate removal of the external green surface of the bamboo in the initial stage of the coating process is expected to enhance the coating adhesion (Wang and Cheng 2020). To date, studies on bamboo wax have primarily focused on the wax components of the leaves; few studies have investigated the distribution and characteristics of the cuticle wax present on the green surface of the stem (He *et al.* 2022).

This study aimed to improve the coating performance of moso bamboo (*Phyllostachys edulis*) through surface pretreatment. The presence and composition of the epidermal wax layer, known to hinder coating adhesion, were analyzed, and surface sanding was performed as a pretreatment to remove this layer. The resultant changes in water contact angle and surface functional groups were examined, and a commercial colored paint was applied to both sanded and unsanded specimens to evaluate the coating performance.

EXPERIMENTAL

Materials

Moso bamboo (age: 3 to 4 years) from the moso bamboo forest test site located in Hacheong-myeon, Geoje-si, Gyeongsangnam-do, Korea (latitude: 34.9292°N, longitude: 128.6806°E) was used as the test material. The culm samples were cut to a size appropriate for analysis in the sanding and coating stages (8 cm × 8 cm). The sanded and coated moso bamboo specimens exhibited an average moisture content of 6.24% and an average density of 0.857 g/cm^3.

Analysis of Moso Bamboo Surface Wax Components

To analyze the wax components that affect the coating performance, a sample of the white powder on the surface of the moso bamboo was collected using a spatula. The sample was mixed with dichloromethane at a ratio of 1:50 (w:v) and the mixture was stirred for 24 h (Fig. 1). The mixture was subjected to centrifugation to separate the supernatant solution. The sample was then subjected to silylation through reactions with 100 μL of pyridine and 10 μL of N,O-bis(trimethylsilyl)trifluoroacetamide. The silylation reaction was performed at 105 °C for 2 h. Next, the sample was analyzed using gas chromatography–mass spectrometry (7890B GC system and 5977A MSD, Agilent Technologies, USA). The analysis conditions were as follows: injection volume, 1 μL; injection mode, split; mobile-phase flow velocity, 1.0 mL/min. The oven temperature was adjusted according to the following schedule: an initial temperature of 80 °C was maintained for 3 min; subsequently, the temperature was increased to 250 °C at a rate of 5 °C/min and then to 300 °C at a rate of 3 °C/min; finally, the temperature was maintained at 300 °C for 20 min to complete the analysis.

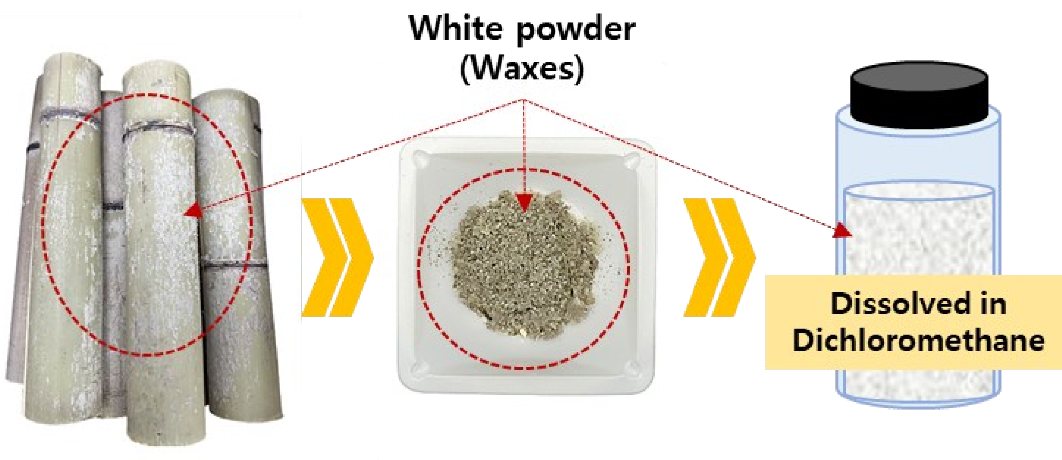

Fig. 1. Sampling of wax substances from the surfaces of bamboo specimens

Analysis of Surface Characteristics with Sanding Treatment

Surface sanding

To examine the effect of the wax in the epidermal layer of the bamboo on the coating performance, the wax-layer distribution and surface characteristics after specific sanding strokes were analyzed. Sanding was manually performed with stroke counts of 10, 20, 30, and 40, using #100 sandpaper. The resultant samples were labeled 10S to 40S, respectively. Sandpaper with a relatively small abrasive-grain size was selected to facilitate uniform surface treatment without fiber damage. Although no defined pressure was applied, the same operator conducted all the sanding by hand, maintaining consistent pressure and speed to ensure uniformity. Sanding was performed along the length of the culm (*i.e.*, in the direction of the longitudinal axis) and repeated according to the same pattern to minimize sandpaper wear. After sanding, the polishing residue on the sample surface was removed using a nylon brush.

Functional-group analysis

The changes in the surface functional groups due to the various sanding treatments (unsanded, 10S–40S) were analyzed using a Nexus 670 FTIR spectrophotometer (Thermo Scientific, Waltham, MA, USA). The curved outer surface of the bamboo culm samples was gently pressed and secured against the attenuated total reflectance (ATR) crystal using a clamp to ensure sufficient contact. The ATR Fourier transform infrared (FTIR) spectrum was measured in the range of 4000 to 400 cm^{-1}. The average spectrum was determined from 64 scans and used to analyze the chemical changes on the surface.

Water contact angle

To evaluate the surface wettability changes caused by the removal of the epidermal layer and the exposure of the fibrous layer according to the sanding stroke count, the water contact angle of each sample was measured at room temperature using a Theta Lite Optical Tensiometer (Biolin Scientific Corp., Västra Frölunda, Sweden). The water contact angle was measured by dropping 10 μL of distilled water (one drop per trial) onto the center of the sample surface. For each sanding condition, three different specimens were tested.

Coating Performance Evaluation According to Sanding Treatment

Surface coating

To establish a constant moisture content, all specimens were dried at 105 °C for 24 h. Unica Super 20 (Tikkurila, Finland) black paint—a commercial colored paint based on an organic solvent—was used for coating. Its properties are presented in Table 1. The coating was applied using a high-volume–low-pressure electric spray gun (FM-500D, Falcon, Taiwan). To ensure uniform application, the application distance was fixed at 50 cm, and a consistent coating speed was maintained. After the first application, samples were dried for 24 h to harden the coating. A second application was performed under the same conditions.

Table 1. Properties of Unica Super 20 Paint Used for Coating

Specification	Details
Paint type	Alkyd resin-based
Specific gravity	0.9 kg/L (based on ISO 2811)
Solid content	38%
Application area	8–10 m^2/L

Water contact angle

The water contact angles of the surfaces of the coated specimens were measured at room temperature using a Theta Lite Optical Tensiometer (Biolin Scientific Corp., Västra Frölunda, Sweden). The specimens were dried for 48 h after coating, and three specimens were tested for each coating condition. The water contact angle was measured by dropping 10 μL of distilled water onto the center of the surface. The surface wettability was evaluated according to the formation of the coating layer on the surface.

Measurement of coating area density

The area density of the paint applied to the samples was calculated to evaluate the application uniformity of the coated moso bamboo. The coating area density, which corresponds to the mass per unit area, was determined by measuring the mass (g) of the specimen before (W_1) and after (W_2) the spray coating treatment and dividing the difference by the area of the specimen (cm²), as given by Eq. 1.

$$\text{Coating area density (g/m}^2\text{)} = \frac{W_2 - W_1}{A} \times 10000 \quad (1)$$

Coating-layer thickness measurement

After spray coating, the coating-layer thicknesses of the sanded and unsanded specimens were measured using an Elcometer 121/4 paint inspection gauge (Elcometer, UK). The maximum measurement range of the blade used was 800 µm, and the blade angle was set to 26.6°. The coating-layer thickness measurements were performed in accordance with the ISO 2808 (2019) standard; the measurement method is shown in Fig. 2. A horizontal baseline was drawn on the specimen surface using the supplied marker (pen); then, the coating layer was cut through application of a constant force in a direction perpendicular to the baseline. The cut cross-section was examined using the magnifying glass attached to the equipment, and the coating-layer thickness was calculated by identifying the number of graticule divisions between the exposed substrate and pen mark. As the cross-section of each bamboo specimen was curved, the coating-layer thickness and adhesion were measured at the center of the surface to ensure measurement consistency.

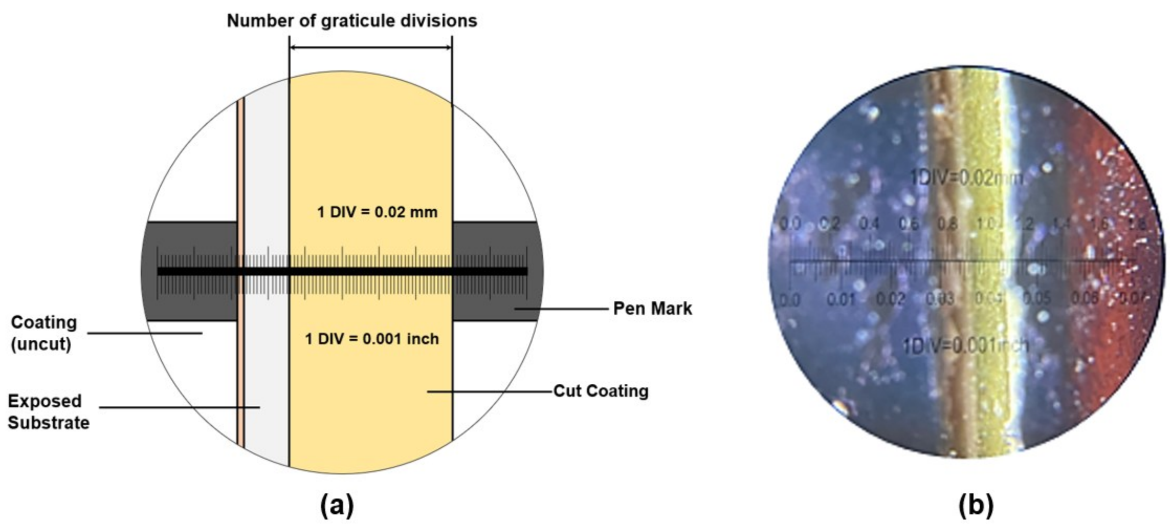

Fig. 2. Schematic of destructive coating thickness measurement (a: measurement method; b: actual measurement)

Coating adhesion evaluation

The coating adhesion was evaluated for each coated specimen in accordance with the sanding treatment using the cross-cut method. The equipment used for the thickness measurement was employed for this evaluation, as shown in Fig. 3. Right-angled grid patterns were formed in horizontal and vertical directions on the specimen surface using the cross-hatch blade. The dedicated tape was then attached and removed. Finally, the coating delamination status was evaluated in accordance with the ISO 2409 (2020) standard. The ISO 2409 grades were classified as 0 to 5, as detailed in Table 2. Grade 0 corresponds to the highest level of adhesion, with smooth cut edges and no delamination or damage to the coating layer.

Table 2. Classification of Cross-cut and Tape Test (According to ISO 2409 2020)

Classification Value	Cross-cut Result
Grade 0	No detachment of the coating at the cross-cut intersections
Grade 1	Detached area is <5%.
Grade 2	Detached area is between 5% and 15%.
Grade 3	Detached area is between 15% and 35%.
Grade 4	Detached area is between 35% and 65%.
Grade 5	Detached area is ≥65%.

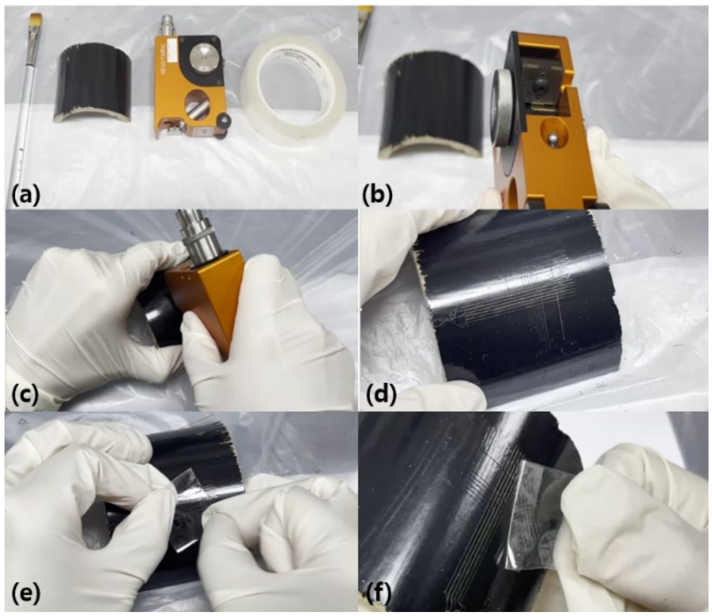

Fig. 3. Procedure of the cross-cut adhesion test using the elcometer for coated bamboo specimens

Accelerated-aging evaluation of coated moso bamboo

To evaluate the effect of UV rays on the deterioration of coated moso bamboo according to sanding condition, an accelerated-aging test was conducted. As before, three specimens were tested for each condition. The UV irradiation conditions were as follows, in accordance with the ASTM G154 (2023) standard: light intensity, 0.89 W/m^2; temperature, 60 °C; light source, UVA-340 lamp. The test was conducted for 168 h using an accelerated-weathering tester (QUV/se Accelerated Weathering Tester, Q-LAB, Westlake, OH, USA). The color changes were measured every 24 h using a colorimeter (CR-10 plus, KONICA MINOTA). Five measurement points were selected on the surface of each specimen, and each measurement was performed three times. The lightness ($L*$), green–red axis ($a*$), and blue–yellow axis ($b*$) values were measured according to the CIELAB color model proposed by the International Commission on Illumination (CIE). Then, the total color change ($\triangle E$) was calculated by substituting these values into Eq. 2 (Hrčková *et al.* 2018; Park *et al.* 2022).

$$\triangle E^* = \sqrt{(L_2 - L_1)^2 + (a_2 - a_1)^2 + (b_2 - b_1)^2}. \quad (2)$$

For $\triangle L^* = L^*_2 - L^*_1$, $\triangle a^* = a^*_2 - a^*_1$, and $\triangle b^* = b^*_2 - b^*_1$, the subscripts 1 and 2 indicate the initial value and the value after the color change, respectively.

RESULTS AND DISCUSSION

Surface Wax Analysis

The white powdery components present on the surface of the bamboo epidermal layer, which has different characteristics from the fibrous layer, are wax and fatty-acid substances (Zhu *et al.* 2024). As these substances may affect the surface coating performance, their composition was analyzed. The results are presented in Fig. 4 and Table 3. Twelve major compounds were identified, including fatty acids, alkanes, and ketones.

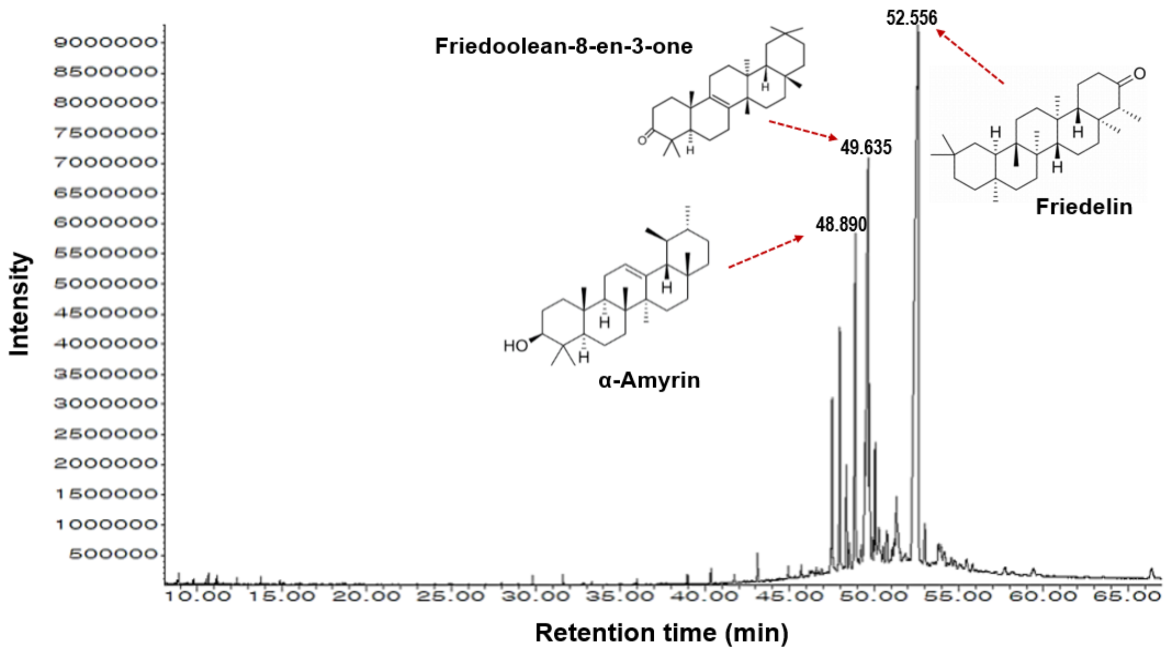

Fig. 4. GC/MS chromatogram of major compounds extracted from the surface of moso bamboo

Table 3. Main Components of the Powdery Wax Layer on the Surface of Moso Bamboo

Retention Time	Compound Name	Type
29.824	Palmitic acid, TMS derivative ($C_{19}H_{40}O_2Si$)	Fatty acids
31.607	Heptadecanoic acid, TMS derivative TMS ($C_{20}H_{42}O_2Si$)	Fatty acids
33.314	Stearic acid, TMS derivative TMS ($C_{21}H_{44}O_2Si$)	Fatty acids
40.345	Heneicosane ($C_{21}H_{44}$)	Alkane
40.345	Octacosane ($C_{28}H_{58}$)	Alkane
44.924	Tetracosanoic acid, TMS derivative ($C_{27}H_{56}O_2Si$)	Fatty acids
47.501	Octamethyl-octadecahydro-picen-3-one ($C_{30}H_{48}O$)	Triterpene
47.977	Labda-8(17),13E-dien-15-ol ($C_{20}H_{34}O$)	Diterpene
48.890	α-Amyrin ($C_{30}H_{50}O$)	Pentacyclic triterpene
49.635	Friedoolean-8-en-3-one ($C_{30}H_{48}O$)	Triterpen
52.556	Friedelin ($C_{30}H_{50}O$)	Ketone
52.593	Friedelan-3-one ($C_{30}H_{50}O$)	Ketone

The bamboo used in this study was also found to contain basic wax components (*e.g.*, C_{16} and C_{18} fatty acids, along with alkanes), which maintain hydrophobicity and provide physical protection from the external environment. Previous research has indicated that the major compounds of the cuticle wax of a bamboo stem are similar to the wax components of Gramineae plants (Cardona *et al.* 2022), and the results of the wax-component analysis performed in this study are consistent with this finding.

Considering the nature of bamboo, KOH and NaOH treatments for pretreatment have been optimized to enhance surface coating performance. For example, chemical treatment for surface dewaxing and mechanical processing methods, such as laser treatment and the use of sanding belts, have been reported (Li *et al.* 2021; Zhao *et al.* 2023; Zhang *et al.* 2025). In this study, sanding treatment was performed to examine the depth of polishing from the surface to the fibrous layer and to investigate the effects of sanding on the resultant coating performance.

Analysis of Surface Characteristics Based on Sanding Treatment

Visual observation

Surface images according to the number of sanding strokes are shown in Fig. 5. White powder components were clearly observed in the unsanded specimen. These components gradually disappeared as the number of sanding treatments increased. In particular, exposure of the cortex and inner pith beneath the epidermis was observed for the 30S and 40S specimens.

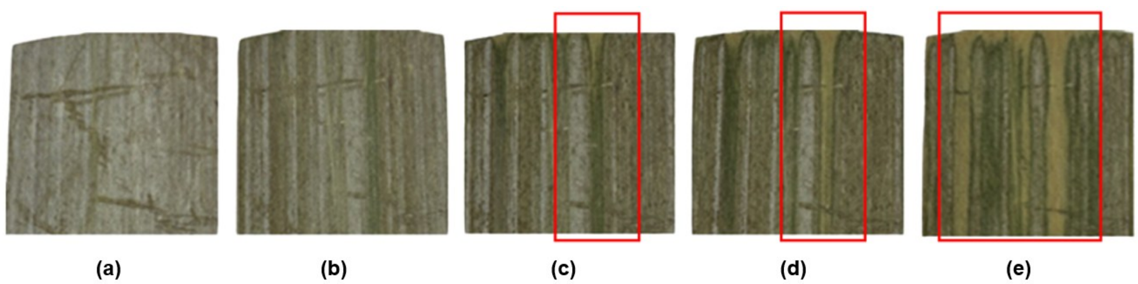

Fig. 5. Surface images after sanding application at different passes: (a) unsanded; (b) 10S; (c) 20S; (d) 30S; (e) 40S

Functional-group changes

The FTIR analysis results according to the number of sanding strokes are shown in Fig. 6. Wax components vary significantly among plant species. In the case of bamboo, fatty acids, alcohols, and esters are the major components, as reported by Racovita and Jetter (2016).

In the spectra, the peaks corresponding to the C–H groups (2950 to 2800 cm^{-1}) and C=O groups (1700 cm^{-1}) of fatty acids and wax decreased in intensity as the number of sanding strokes increased. However, the intensities of the peaks in the range of 1100 to 1000 cm^{-1} increased markedly for the 20S and 30S samples. This increase is attributed to the increase in the content of glycosidic bonds (C–O–C), which are the representative functional groups of cellulose and hemicellulose (*i.e.*, fiber components), as the fibrous layer of the bamboo was exposed by the abrasion of the epidermal layer (Wang and Ren 2008; Khan *et al.* 2018). Consequently, the components of the epidermis and cortex were altered as the number of sanding strokes increased. However, peak changes no longer occurred for $\geq$40 sanding strokes.

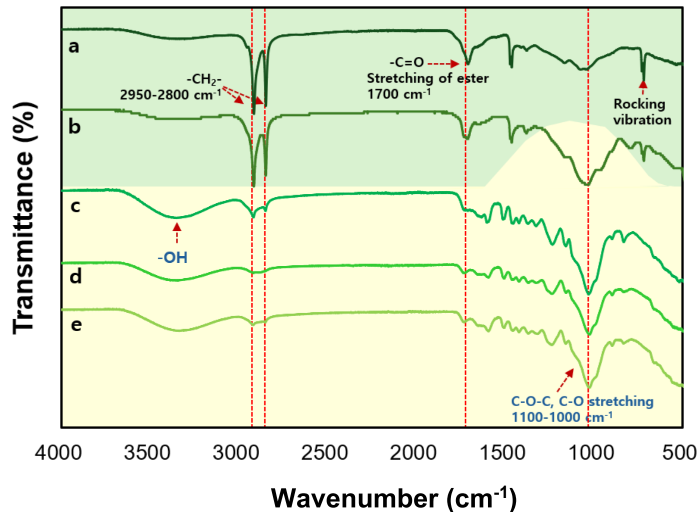

Fig. 6. FTIR spectra of bamboo samples: (a) unsanded; (b) 10S; (c) 20S; (d) 30S; 40S

Water contact angle

The initial contact angle, *i.e.*, that for the epidermis of the unsanded specimen, was 78.59°, as shown in Fig. 7. This value decreased by 12.68° to 65.91° in 20 s. Compared to ordinary flat materials, the contact angle was relatively low even for the unsanded specimen. For ordinary materials, contact angles lower than 90° indicate hydrophilicity, whereas higher values indicate hydrophobicity (Chen *et al.* 2022). In this study, contact angles lower than 90° were obtained despite the presence of the wax layer, because cylindrical bamboo samples were used.

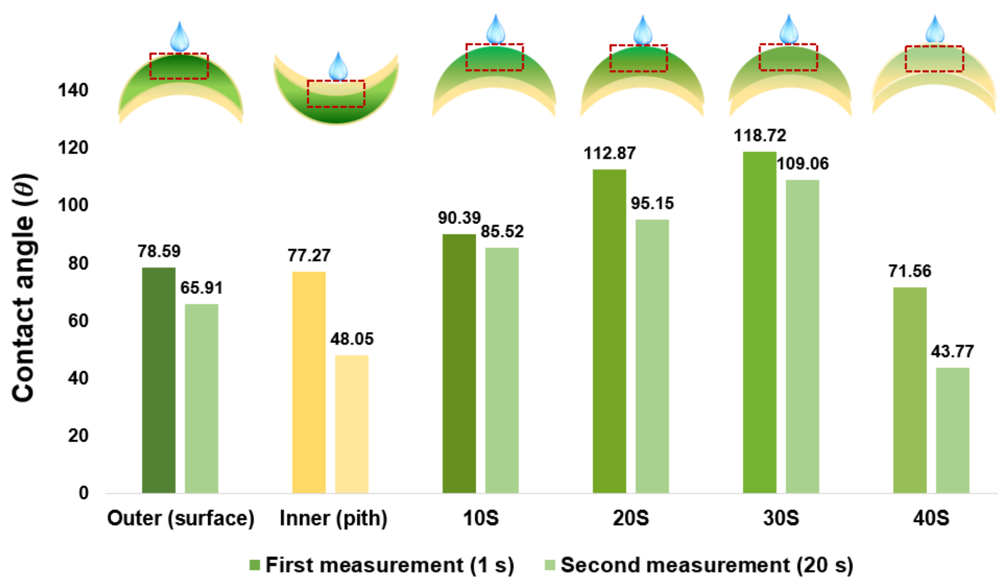

Fig. 7. Contact angles on the surfaces of bamboo samples

The wax layer is a characteristic surface feature of bamboo. In this study, samples of the inner pith of the bamboo, *i.e.*, the fibrous layer, were taken as a control group, and their contact angles were measured. The initial contact angle was 77.21°, whereas that after 20 s was 48.05°, corresponding to a reduction of approximately 30°. Thus, significant differences from the outer layer of the bamboo were observed; these differences were due to the tissue layer, which primarily comprised polysaccharides. For S10–S30, the contact angle increased continuously. Higher contact-angle values were observed compared to those of the untreated specimens.

The wax layer in the surface epidermis was irregularly removed depending on the number of sanding strokes and adhered to the surface in the form of foreign substances, yielding mixed aggregates of wax materials. This appears to have been because 30 sanding strokes were insufficient to expose the inner pith. The S40 specimens exhibited a change of 27.8° in the contact angle, from 71.6° at the beginning to 43.8°. This change in contact angle is similar to the contact-angle measurement results for the inner piths of the unsanded specimens (a reduction of 29.2°, from 77.2° to 48.0°).

Therefore, the wax components of the epidermis were effectively removed under 40 sanding strokes, with the surface wettability becoming similar to that of the inner pith because of the exposure of the fibrous layer. It appears that the wettability improvement effect was limited when considering 10 to 30 sanding strokes, because the sanding depth could not reach the critical level. However, significant wettability changes were observed after ≥40 sanding strokes. According to these results, the untreated specimens and the specimens subjected to 40 sanding strokes were intensively compared in the context of the coating treatment performed after surface sanding.

Analysis of Surface Coating Layer Based on Sanding Treatment

From the analysis of the surface characteristics according to the number of sanding strokes reported in the previous subsection, 40 stroke counts was the optimal sanding condition in this study. Accordingly, the S40 specimens were selected as a control group for analysis of the coating performance.

Water contact angle

Figure 8 shows the contact-angle measurement results for the coated specimens according to the sanding condition. The initial (1 s) contact angle of the unsanded specimens was 88.0°, which decreased by 7.0° to 81.0° in 20 s.

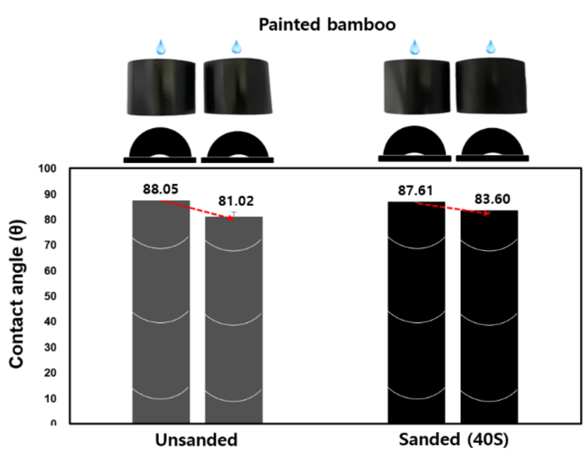

Fig. 8. Changes in contact angle over 1 and 20 s on painted bamboo (unsanded and sanded)

The contact angle of the sanded specimens decreased by 4.0°, from 87.6° to 83.6°. Therefore, for both coated specimens (unsanded and 40S), the reduction in contact angle over time was small. This outcome is attributed to the formation of a surface coating through the coating treatment. As the most representative wood protection treatment, coating application is expected to inhibit moisture infiltration from the outside and microorganism growth by blocking functional-group changes and pore structures on the bamboo surface (Guan *et al.* 2022).

Coating area density and coating-layer thickness

The coating layer formed through surface coating protects the surface from the external environment; thus, an insufficient coating-layer thickness increases the probability of damage and delamination of the coating. In particular, the formation of a thin coating layer may cause uneven paint-color development or disclosure of the basic material color, degrading the appearance of the bamboo and causing problems for long-term use. Figure 9 shows the coating area density and coating-layer thickness measurement results for the sanded and unsanded specimens.

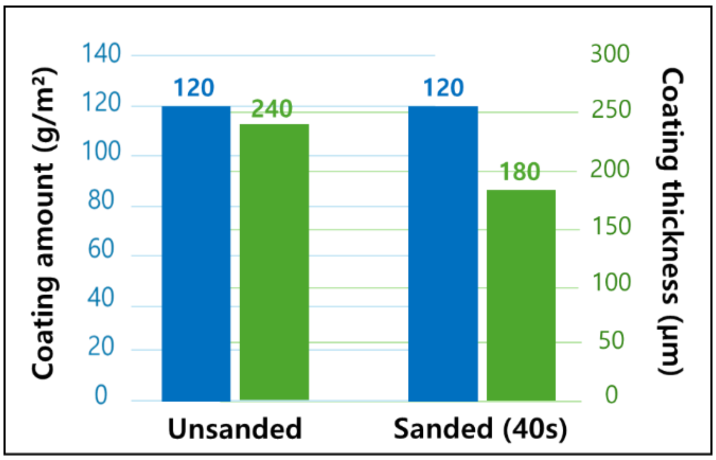

Fig. 9. Coating amount and thickness for unsanded and sanded moso bamboo

For both treatment groups, the same average coating application amount was used (120 g/m², based on the total paint applied). The standard deviations were small—in the range of 0.16 to 0.20—indicating that the process was uniformly performed and confirming the reliability of the coating performance evaluation results. When the solid content (38%) of the commercial paint was considered, the appropriate coating area density calculated according to the manufacturer's specifications was 34.2 to 42.8 g/m², and the coating area density measured in the experiment was 45.6 g/m². Although it was slightly higher than the recommended range, this value was judged to be within the practical range.

For the unsanded and sanded specimens, the coating-layer thickness was measured to be 240 and 180 µm, respectively. Thus, the coating-layer thickness of the unsanded specimens was about 60 µm greater than that of the sanded specimens. This difference is attributed to the formation of a thinner and more adhesive coating layer under the same application conditions, as the sanding treatment removed the surface wax layer and allowed the paint to effectively contact the fibrous layer of the surface.

Aykac (2021) reported that such smooth and uniformly sanded bamboo surfaces induce uniform application and stable adhesion of paint, enhancing coating quality and product appearance.

Coating adhesion grade

The coating adhesion evaluated for the coated specimens according to the sanding treatment was the key indicator in this study. Images showing the evaluation of the coating adhesion performance with respect to the sanding conditions are presented in Fig. 10. Coating delamination was observed for the unsanded specimen owing to the weak adhesion of the paint. However, the adhesion of the sanded specimen (40S) was evaluated as Grade 1 based on the ISO standard; thus, this specimen exhibited significantly improved adhesion. This outcome is attributed to the fact that the sanding treatment before coating improved the interface adhesion between the paint and the moso bamboo surface.

Stojanović *et al.* (2023) also reported that the adhesion performance of paint is significantly affected by both its composition and the surface pretreatment method and that sanded specimens exhibit superior and more consistent adhesion characteristics compared to untreated specimens.

Therefore, for moso bamboo, paint adhesion should be improved through effective surface pretreatment processes, such as sanding, to ensure the long-term durability of the coated material.

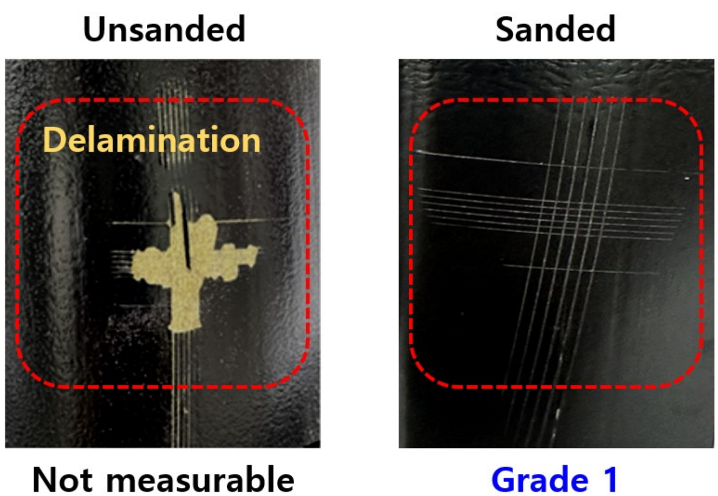

Fig. 10. Surface appearance of moso bamboo specimens after 168 h of UV exposure

Coating Deterioration Evaluation Based on Accelerated-aging Testing

Visual observation of coating adhesion

Durability evaluation to determine the service life of the material following coating is also important. In this study, accelerated aging was conducted *via* UV irradiation only, without wetting or water spray. Accordingly, following coating with the commercial paint, the sanded and unsanded moso bamboo specimens were irradiated for 168 h, and subsequently, the coating adhesion was examined. The results are shown in Fig. 11. For the unsanded specimen, the paint adhesion was considerably weak, and paint delamination occurred over time. This appears to have been because the paint adhesion was reduced by the chemical changes and mechanical damage of the surface caused by the UV rays. Although no defects were observed in the sample images obtained after coating (Fig. 8), differences were confirmed after UV irradiation. Nonetheless, despite the UV irradiation, the sanded specimen maintained excellent coating adhesion characteristics, and neither coating delamination nor cracking was observed.

Raw bamboo exhibits color changes and deterioration when exposed to UV rays. Such phenomena are accelerated by UV-induced photodegradation (Correal *et al.* 2025). Modification technology to change the characteristics of bamboo, along with the application of UV-protective coatings, has been proposed to mitigate the impact of UV rays (Yang *et al.* 2022). Therefore, pretreatment processes, such as sanding, in conjunction with coating treatment are essential to enable long-term utilization of bamboo in external environments.

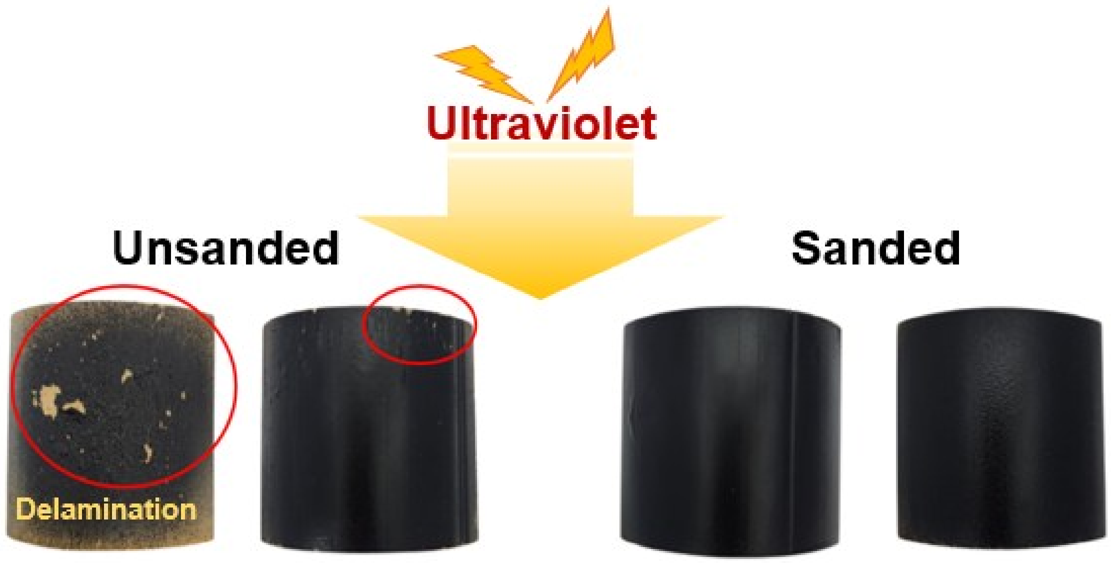

Fig. 11. Surface appearance of moso bamboo specimens after 168 h of UV exposure

Color changes due to UV irradiation

As indicated by Table 4 and Fig. 12, the color changes before and after UV irradiation were limited regardless of the sanding condition. The changes in L^*, a^*, and b^* were minimal, and the ΔE values were 0.65 for the unsanded specimens and 0.69 for the sanded specimens, both far below the level perceptible to the naked eye.

According to Kelkar *et al.* (2023), for coated specimens, the color-change resistance to UV irradiation was significantly improved, and the brightness stability was enhanced. Kim *et al.* (2024) UV-irradiated raw moso bamboo and obtained $\Delta E = 8.4$. This indicates that long-term color stability can be expected after the coating treatment. Notably, there was no difference in color change depending on whether sanding was performed before the coating treatment.

Table 4. L^*, a^*, and b^* Values and Their Changes (Δ) Before and After UV Exposure for Sanded and Unsanded Specimens

Sample	L^*_{before}	L^*_{after}	ΔL^*	a^*_{before}	a^*_{after}	Δa^*	b^*_{before}	b^*_{after}	Δb^*
Unsanded	16.2 ± 0.8	15.7 ± 0.5	–0.5	5.5 ± 0.2	6.0 ± 0.4	0.5	6.3 ± 0.6	7.0 ± 0.7	0.7
Sanded	16.4 ± 0.8	16.2 ± 0.9	–0.2	5.5 ± 0.3	5.7 ± 0.2	0.2	6.2 ± 0.6	6.7 ± 0.2	0.5

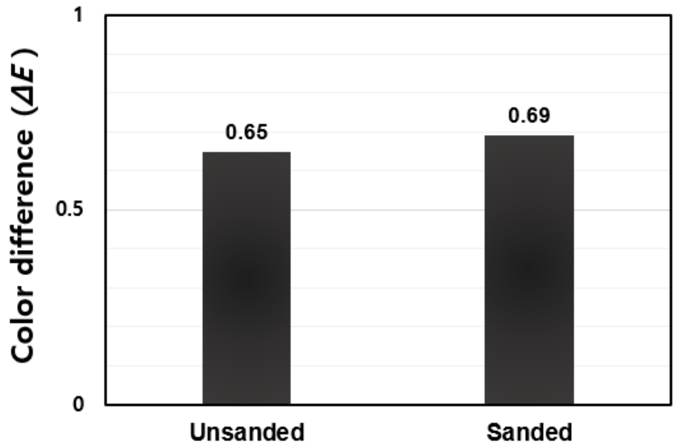

Fig. 12. Color-difference variation of coated moso bamboo

Although manual sanding has limitations in terms of precision and reproducibility, this study is significant in that it tracked the changes in each layer of the bamboo surface in stages. On the basis of the results, a mechanical polishing process will be introduced in future research to ensure operational efficiency and economic feasibility. Furthermore, various studies will be performed with the aim of enabling broader commercial application of bamboo.

CONCLUSIONS

1. Changes in moso bamboo surface characteristics induced by hand sanding were analyzed.
2. The wax in the epidermal layer of the bamboo weakened the coating adhesion, and conversely, the exposure of the fibrous layer significantly enhanced the coating adhesion.
3. Excellent coating adhesion was observed for the specimens subjected to 40 sanding strokes (40S), which exposed the fibrous layer, as indicated by a Grade-1 adhesion evaluation based on ISO 2409 (2020). This result clearly indicates the need for bamboo surface pretreatment.

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