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**Research Article**

# Environmentally Friendly Surface Treatment Agent Trial on Wood Material and Its Effect on Adhesion Resistance

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***Abstract*** – Wood preservatives, widely used in the wood industry, pose a risk to human health and the environment due to their harmful chemical structure. Due to the awareness of society and environmental pressures, it is searching for natural preservatives compatible with the ecological environment. Resins, which do not contain any hardening and toxic chemicals in their components, have been preferred as surface treatment materials since ancient times due to their water-repellent properties and compatibility with wood materials. This study aimed to determine the adhesion effect of resin-based lacquer used in lacquering food packaging materials, which does not contain hardeners and harmful solvents, as a surface protector on wood materials.

The study preferred three local wood species and resin lacquer (food lacquer) as surface treatment materials. In this context, samples prepared from Oriental beech (*Fagus Orientalis* Lipsky), Scots pine (*Pinus Sylvestris* L.), and Anatolian chestnut (*Castanea sativa* Mill.) according to ISO 3129 principles were acclimatized by TS ISO 13061-1 principles and resin lacquer was applied to the surface of the test samples by spraying method according to ASTM-D 3023 principles. After the surface treatment, the samples were cured (hardener) in an oven (fan-drying oven) at temperatures of 60, 80, and 100 °C. The samples coated with resin lacquer were measured for adhesion according to TS EN ISO 4624. The test data were subjected to statistical analysis in the MSTAT-C program. According to the results, the analysis of variance regarding the effects of wood species and temperature on the adhesion value was found to be statistically significant ($\alpha$=0.05) regarding wood species and temperature changes but insignificant in terms of their interactions. In the interaction of wood species and oven temperature, the highest surface adhesion value was obtained at Oriental beech + 100 °C (2,821 N/mm²) and the lowest at Scots pine + 60 °C (2,00 N/mm²).

*Keywords – Adhesion, Wood Material, Human/Environmental Health, Ecological Surface Material, Resin Lacquer*

## I. INTRODUCTION

Studies have shown that many of the varnishes used in the wood industry are artificial and pose major hazards to human health [1]. Today, the search and studies for the environmentally friendly, antibacterial upper surface matter that will eliminate or reduce these drawbacks are rapidly continuing by the sector's R&D units and scientists. As the importance of environment/human health increases, countries are introducing more innovative/protection-oriented approaches/standard practices, natural paints/varnishes are gaining importance instead of very harmful synthetic materials, and humanity demands such materials [2-4]. Nowadays, the "green wave" movement has occurred with the increasing interest in products that do not have toxic or harmful effects, which will produce environmentally friendly, healthy products by obtaining natural dyes/preservatives [5, 6].

Nowadays, upper surface matter that provides more protective layers is used to protect furniture/decoration elements produced with wooden materials and some building elements [7]. In industrial practice, solvent-based solvent (thinner) and chemical-based hardener varnish-paint systems are used to protect the surface structure of wooden materials. The primary reason for the widespread use of water-based paint/varnish is to increase the diversity of resin compounds that form a layered structure by developing them [8].

It is thought that in Turkey, non-wood forest products such as tar, resin, essential oils, wax and polishing materials, and organic compounds as solvents such as alcohol are not used much as wood upper surface matter. In recent years, scientific research on the use of upper surface matter obtained from natural plant dyes has increased [9].

Meijer and Militiz (2000) conducted a study on low-emission surface treatment materials adhesion. It has been determined that alkyd-based varnishes give higher adhesion values than acrylic varnishes. They concluded by analyzing the interaction between varnish and wood species using an electron microscope [10]. Altun and Esmer (2017) studied the surface preparation process in heat-treated wood materials and the effect of varnish type and adhesion resistance of varnishes [11]. It is stated in the literature that there are differences between the adhesion resistance of varnishes on deciduous trees and coniferous trees. It is stated that the adhesion resistance of varnishes is high in leafy trees, and the trees with low adhesion resistance are coniferous. Polyurethane and acrylic varnish, which completes its polymerization on the wooden material's surface, have the highest adhesion resistance. However, it has been stated that porous wood materials such as beech and fir should be avoided in works that require high adhesion resistance [12].

Nelson (1995) stated that adhesion on protective layers can be measured, but the measurement cannot give definitive results. Although the tests performed for measurements provide information about relative adhesion performance, it has been pointed out that the physical force in adhesion cannot be explained precisely [13].

Shakri (1995) examined the surface treatment properties of glossy paint, cellulosic, polyurethane, and acid hardener varnishes by applying them to three types of trees in Malaysia and found that polyurethane varnish had the highest adhesion values, glossy paint the lowest, and that the surface treatment properties were determined according to the tree species. He concluded that it has changed [14].

Kaygın (2017), in his study using synthetic, acrylic-based opaque and cellulosic paints, stated that wood materials do not affect the adhesion resistance of the varnish; the change depends on the type of paint used, and synthetic paint provides the most change [15].

Sarı and Özalp (2018) added different amounts of aluminum sulfate to the polyurethane varnish used on wooden materials and applied it to Scots pine and beech wood surfaces. They determined the effects of aluminum sulfate added to polyurethane varnish by performing surface adhesion resistance tests on the samples. As a result of the study, they found that the adhesion resistance was significantly reduced by adding aluminum sulfate to the varnish [16].

Karakoç (2020) applied synthetic and chlorine rubber paints to local tree species and investigated the layer properties formed by using them in yacht and wooden boat construction [17]. Peker (1997) investigated the color, brightness, surface adhesion resistance, and hardness values of Scots pine and chestnut wood by keeping them under open-air conditions after the impregnation and varnishing process. As a result of the research, it was stated that chestnut wood showed less color change when left outdoors than Scots pine wood and that polyurethane varnish affected the hardness of chestnut and Scots pine wood to the first degree and synthetic varnish to the second degree [18].

Budakçı (1997), after applying different varnish types to wood materials, examined the surface adhesion resistance, hardness, and gloss value of the varnish layer thickness and found that acrylic as the varnish type and oak as the wood type had the highest value in the layer thickness resulting from 3-layer application in surface adhesion resistance. It was concluded that synthetic varnish had the most negligible value as varnish type, and pine and beech trees had the most negligible value as layer thickness in the 1-coat application and wood type [19].

The study aims to contribute to science/research by using a product that respects people/environment as a surface treatment agent on wooden materials. Considering health, safety, and environmental issues, it was developed from resin-based products; “gold food lacquer,” suitable for food and drug contact, was preferred as a commercial product.

## II. Materials and Method

### A. *Materials*

The study preferred beech, Anatolian chestnut, and Scots pine as wood materials. Wooden materials were selected randomly from timber companies operating in Afyonkarahisar and processed according to ISO 3129 principles [20].

The study preferred beech, Anatolian chestnut, and Scots pine as wood materials. Wooden materials were selected randomly from timber companies operating in Afyonkarahisar and processed according to ISO 3129 principles.

A unique packaging coating (armouring) material known as "Gold food lacquer" obtained from organic polymer resins was tested as a surface treatment agent. Although food lacquer may seem simple, it is preferred in all food packaging purchased by humanity (cheese, tomato paste, oil, vinegar, olives, fish, canned food, etc.) and appeals to various areas regarding its usage level. Especially since food packaging materials are not protected against corrosive effects, the tin layer surface must be covered with an organic material. The coating material obtained from resin is called "Lac". Lacquer material is very resistant to acids, salts, high sterilization resistance, and corrosion after hardening by baking on the surface of the material, and it does not dissolve in many organic or chemical solvents on the surface. The manufacturer supplies the resin lacquer in pure form, and has been modified to a viscosity applicable to wooden materials and at temperatures that allow it to solidify [21-22]. Reçine lakı, Manisa ili Keçiliköy OSB bölgesinde faaliyet gösteren TOYO firması metal ambalaj sistemleri firmasından temin edilmiştir. Lak, 13.78 Ph, 1.017 gr/cm³ yoğunluk, 20- 25°C’de 28-30 sn DIN Cup/4mm viskozite, %50-55 katman yapma özelliğindedir [23].

### B. *Method*

Test samples were prepared according to ISO 3129 from the sapwood section, which had no knots, cracks, or a smooth fiber structure, was not damaged by fungi or insects, and had no discoloration [20]. Cuttings were made in the furniture workshop of Afyon Vocational School, and 120 (10x4x3) test samples were prepared, including three wood types, three different temperatures, and one control, with ten repetitions for each parameter. Samples with net dimensions of 100x100x10 mm (longitudinal direction × radial direction × tangential direction) in air-dry humidity were conditioned at 20±2°C/65±5% conditions, and the sample humidity was brought to 12±2% [24]. Then, the sample surfaces were sanded with sandpaper numbers 80 and 120, respectively, and the dust on the surface was cleaned with compressed air. The resin lacquer was applied 2 (28 times) with an air gun with a 1.8 mm tip opening, perpendicular and parallel to the fibers, at a rate of 125 g per m². It was applied in two layers at atm pressure [25]. After baking between coats, it was sanded with 400 numbered sandpapers. The varnishing process was based on ASTM-D 3023 standard [26]. The varnished samples were dried in a fan oven at three different temperatures (60 / 80 / 100°C). They were kept in the oven for 120 minutes at 60℃ temperature, 90 minutes for 80℃, and 60 minutes for 100℃ temperatures to ensure complete drying. Before the measurements, the samples were kept in an environment of 23 ± 2℃ and 50 ± 5% relative humidity until they reached a constant weight, according to TS EN ISO 4624 principles [27].

The adhesion strength of the surface treatment agent to the surface was determined according to TS EN ISO 4624 principles. An adhesion test device operating with a pneumatic system was used [27]. The adhesion test device is given in Fig 1.

Fig 1. Ahesion testing device

The samples, coated with resin lacquer and left to dry, were then glued to a cylindrical metal device with a radius of 10 mm with “Penloc-GTI” brand two-component acrylic-based adhesive. After the cylindrical apparatus used in the experiment was glued to the surface, they were left to print in specially made molds and dried for one day at room conditions (23±2 °C). Then, excess glue burrs around the samples removed from the mold were cleaned with a cutting apparatus. The cylinder adhered to the surface was removed from the surface with a unique device designed to determine the adhesion resistance, working with a pneumatic system. The force at the last breaking moment is automatically displayed on the digital screen. The tensile stress was detached by slowly stretching at a constant speed, not exceeding 1 MPa/s, as stated in the "TS EN ISO 4624" principles. The full rupture time was achieved within 1.5 minutes in each test sample.

In the experiments, adhesion resistance (X);

$X=4F/\pi .\ d^2$ MPa calculated from equation.

Here;

F = Force at break, (Newton)

d = Diameter of the test cylinder, (mm).

The glue used to adhere the metal cylinder to the surface of the test samples is Penloc-GTI” brand adhesive, which is two-component, acrylic-based, has no effect on dissolving the surface treatment agent, has high adhesion on metal-wood surfaces, and is sold in 50-gram tubes, was used. The properties of the glue and the principle of adhesion to the surface were adhered to according to the calculation of 150±10 g/m² specified in TS EN ISO 4624 principles [27].

### C. *Evaluation of data*

120 samples (3x4x10) were prepared, including ten replicates for 3 wood types, 3 drying temperatures + 1 for control. Multiple analysis of variance was used between groups to determine the difference in adhesion resistance values of the prepared samples. Whether the difference was significant between groups was determined by the "DUNCAN TEST".

## III. DISCUSSION

Adhesion values obtained according to tree type are given in Table 1.

Table 1. Ağaç türüne göre elde edilen yüzey yapışma değerleri (MPa)

| Wood Species | $\bar{X}$ (MPa) | HG |
|---|---|---|
| Oriental beech (Ob) | 2,617 | A |
| Anatolian Chestnut (Ac) | 2,466 | A |
| Scots pine (Sp) | 2,159 | B |
| *LSD= 0.2315* | | |

In terms of tree species, the surface adhesion value was found to be highest in Oriental beech (2,617 MPa) and lowest in Scots pine (2,159 MPa). Surface adhesion value was found to be different among tree species. However, similar values were found between Oriental beech and Anatolian chestnut. Surface adhesion values determined according to tree type are shown in Fig. 2.

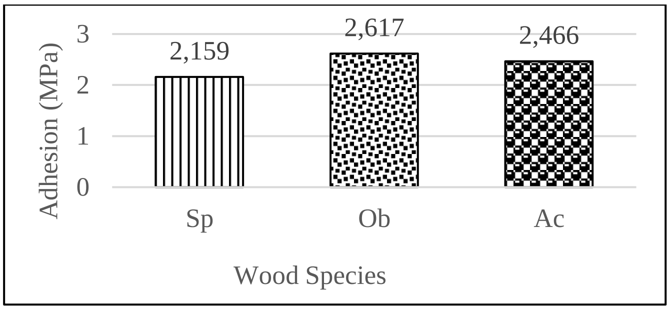


Fig 2. Surface adhesion variations according to tree type

Surface adhesion values obtained according to temperature are given in Table 2.

Table 2. Surface adhesion values obtained according to temperature (MPa)

| Temperature (°C) | $\bar{X}$ (MPa) | HG |
|---|---|---|
| 100 ºC | 2,614 | A |
| 80 ºC | 2,423 | AB |
| 60 ºC | 2,204 | B |
| *LSD= 0.2315* | | |

Regarding temperature, the highest surface adhesion value was obtained at 100 °C (2,614 MPa) and the lowest at 60 °C (2,204 MPa). There is no significant difference in surface adhesion values in terms of temperature. Surface adhesion values determined according to temperature are shown in Fig 3.

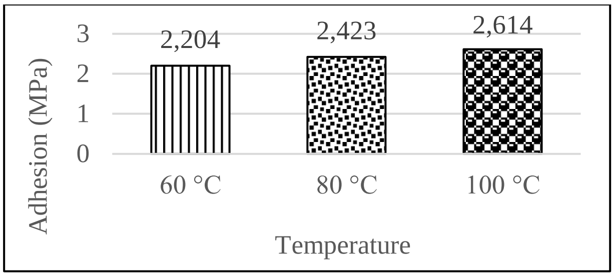


Fig 3. Surface adhesion changes according to temperatures

Multiple variance analysis results regarding the effects of wood material type and temperature on surface adhesion value are given in Table 4.

Table 4. Multiple variance analysis on the effects of tree species and temperatures on surface adhesion values

| Factor | Degrees of freedom | Sum of squares | Mean of squares | F Value | P<0,05 |
|---|---|---|---|---|---|
| Wood Species (A) | 2 | 3.279 | 1,640 | 7,9934 | 0,0007 |
| Temperature (B) | 3 | 2,524 | 1,262 | 6,1537 | 0,0033 |
| AB | 6 | 0,214 | 0,054 | 0,2614 | - |
| Error | 108 | 16,614 | 0,205 | | |
| Total | 119 | 22,632 | | | |

The effects of tree species and temperature on surface adhesion values were statistically significant (α=0.05) regarding tree species and temperature changes but insignificant regarding their interactions. The results of the Duncan test, which was performed to determine which groups the difference is significant, are given in Table 5.

Table 5. Surface adhesion DUNCAN test results (MPa)

| Wood Species X Temperature (AB) | $\bar{X}$ (MPa) | HG |
|---|---|---|
| Ob+100 ºC (Ob+100) | 2.821 | A |
| Ac+100 ºC (Ac+100) | 2.703 | AB |
| Ob+80 ºC (Ob+80) | 2.581 | ABC |
| Ac+80 ºC (Ac+80) | 2.531 | ABC |
| Ob+60 ºC (Ob+60) | 2.450 | ABC |
| Sp+100 ºC (Sp+100) | 2.319 | BCD |
| Ac+60 ºC (Ac+60) | 2.163 | CD |
| Sp+80 ºC (Sp+80) | 2.157 | CD |
| Sp+60 ºC (Sp+60) | 2.000 | D |
| *LSD= 0.4009* | | |

The highest surface adhesion value was obtained for Oriental beech at + 100 °C (2,821 MPa) and the lowest for Scots pine at + 60 °C (2 MPa). Changes in surface adhesion values determined by tree type and temperature are shown in Fig. 4.

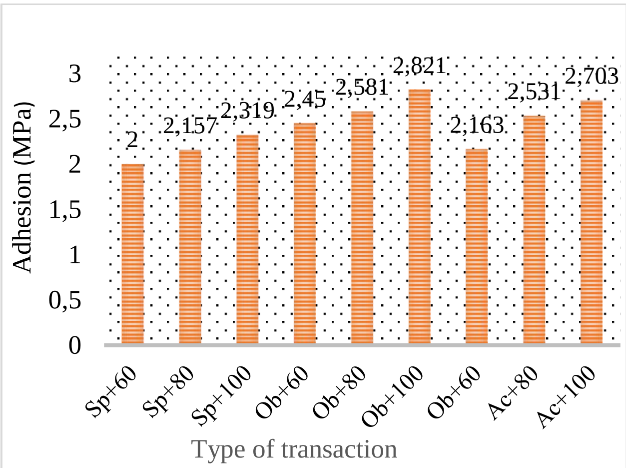


Fig 4. Surface adhesion changes according to process type

## IV. CONCLUSION

The highest surface adhesion value obtained according to tree type was obtained in Oriental beech (2,617 N/mm²), Anatolian chestnut (2,466 N/mm²), and Scots pine (2,159 N/mm²), respectively. The high adhesion resistance of Oriental beech may be due to the wood's unique and robust adhesion on the surface due to its dispersed small trachea and homogeneous structure. The highest surface adhesion values obtained according to the oven temperature were obtained at 100 °C (2,614 N/mm²), 80 °C (2,423 N/mm²) and 60 °C (2,204 N/mm²), respectively. It is thought that as the oven temperature increases, the surface adhesion values partially increase in parallel.

In the analysis of variance regarding the effects of tree species and temperature on the surface adhesion value, it was found to be statistically significant ($\alpha$=0.05) in tree species and temperature changes but insignificant in terms of their interactions. In the wood-type oven temperature interaction, the highest surface adhesion value was obtained for Oriental beech at + 100 °C (2.821 N/mm²), and the lowest was obtained for Scots pine at + 60 °C (2.00 N/mm²).

It is known that there is roughness in the wood material cut along the intercellular and lumen spaces of the cells. Mechanical adhesion can be established between the varnish and the surface, filling these gaps in liquid form and hardening where filled [28]. The literature has reported that cohesion increases as the molecularity increases, and adhesion increases as the molecularity decreases [29].

In her study, Tutgun (2013) applied water-based, polyurethane, and acrylic varnishes to cherry, Oriental beech, and Scots pine test samples. As a tree species, the adhesion level is highest in cherry (2.52 N/mm²), lowest in Scots pine (2.32 N/mm²), and when examined as a varnish type, polyurethane varnish has the highest (3.15 N/mm²) and water-based varnish (3.15 N/mm²). The lowest (1.87 N/mm²) was obtained. Acrylic varnish; Oriental beech (2.20 N/mm², Scots pine (2.29 N/mm²) and cherry (2.27 N/mm²), polyurethane varnish; Oriental beech (3.29 N/mm²), Scots pine (2.76 N) /mm²) and cherry (3.38 N/mm²), water-based varnish; Oriental beech (1.79 N/mm²), Scots pine (1.92 N/mm²) and cherry (1.90 N/mm²) [30]. According to these results, the resin lacquer used in the study showed better adhesion resistance than water-based varnish and lower performance than polyurethane varnish. It can be compared to acrylic varnish, showing close adhesion performance.

The application cost of resin lacquer on wooden materials is approximately the same as other industrial varnishes (cellulosic, synthetic, yacht varnish, etc.). However, since surface hardness is done using a drying oven, the oven has an additional energy cost. This cost varies depending on the type and capacity of the drying oven and is estimated to be between 3-8%. Lacquers are used in nearly 150 food packaging companies in Turkey. In this respect, it can be supplied in sufficient quantities if used in the wood industry and can be adapted to the sector with the same drying method.

In light of the literature, the difference of this study from other studies is the use of melts that can form a film layer in varnishes, resins in the thermoset group, the preference of organic compounds instead of harmful solvents as thinners, and the use of heat as a hardening catalyst. In this respect, a product that is more respectful to nature and human health can be recommended as a surface treatment agent for wood materials. The area of use of this product is wooden children's toys, hospital venues, sterile areas, pharmacies, etc. Especially in areas with wood-based materials used in the kitchen (forks, knives, serving plates, chopping boards, etc.), children's playgrounds, dining table surfaces, nursery and kindergarten furniture, beehives, wood-based barrels, etc. It will be suitable for use in products and all indoor environments. In the continuation of the study, it may be recommended to determine the entire surface performance of resin lacquer on wooden materials against indoor and outdoor weather conditions and compare it with other alternative products [9].

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