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WETTEBALITY, WATER ABSORPTION AND THICKNESS SWELLING OF PARTICLEBOARD MADE FROM REMEDIATED CCA-TREATED WOOD[1)]

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Kısa Özet

Composite production is one of the most attractive alternatives for the recycling of chromated copper arsenate (CCA) treated wood. In this study, wettability, water absorbance, and thickness swelling of particleboard samples made from untreated, CCA-treated, oxalic acid (OA) extracted, and bioremediated wood particles were investigated. Wettability, water absorption and thickness swelling decreased in particleboard samples containing CCA-treated particles. However bioremediation of CCA-treated wood particles using *Bacillus licheniformis* has negative effect on board surface in terms of these properties.

1. INTRODUCTION

One of the most attractive alternatives for the spent-treated wood is to convert this high-quantity resource into composite products. Recycled treated wood can be a good source for fiberboard, particleboard, oriented strand board, or cement-bonded boards. Several studies have suggested that the properties of composite products made from chromated copper arsenate (CCA)-treated waste wood may be lower than those of untreated wood particles and these reductions in properties can be attributed to the surface modification by the interaction between preservative components and resin (MUNSON/KAMDEM 1998). Novel approaches such as acid extraction and bioremediation to remediate CCA-treated waste wood can substantially reduce the amount of copper, chromium, and arsenic in treated wood waste.

Wettability of a solid surface by a liquid is usually expressed as the contact angle between the solid and the liquid, a smaller contact angle signifying greater wettability (ADAMSON 1982). The contact angle between wood and a liquid depends on many factors, such as wood species, extractives present in wood, wood anatomy, wood surface sections, wood seasoning, moistu-

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re content, relative humidity, temperature, surface roughness, previous history (exposure to water, light, weathering, or biological attacks), and aging of exposed surface. Wettabality on wood is of importance because bond quality in composites is affected by the contact of the glue with wood and is a good indicator of the glue (MALDAS/KAMDEM 1999; KALNINS/KNAEBE 1992).

Previous studies on the wettability of wood have primarily focused on three areas: (a) elucidation of basic material properties of wood, (b) study of changes in basic material properties of wood, and (c) improvement or adaptation of experimental methods for tests on wood (KALNINS/KNAEBE 1992).

The affinity of wood for water is attributed to two hydroxyl-containing components, cellulose and hemicellulose (ROWELL/BANKS 1985). On the other hand, extractives can provide some water repellency, especially in softwoods.

Preservative treated wood either does not adhere properly to conventional thermosetting wood adhesives, or the glue line fails. To develop good adhesion between adhesive and CCA-treated wood, a basic understanding of the interface between wood surface and glue is important (MALDAS/KAMDEM 1998). The surfaces of CCA-treated wood cell walls are covered with mixtures of chromium, copper, and arsenic, which block adhesion to CCA-treated wood (VICK/KUSTER 1992).

With the overall goal of evaluating the recycling potential of CCA-treated and remediated waste wood with oxalic acid and bacterial decomposition for composite material production, the objective of this study is to determine the wettability of the surfaces of particleboard made from oxalic acid extracted and bioremediated CCA-treated wood by means of contact angle measurements. Beside contact angle, water absorption and thickness swelling of board samples were also determined.

1.2 Theory

Spreading of a liquid on a solid depends on relative magnitudes of the inter-and intramolecular forces of attraction of the liquid and solid substrate at the interface. Young`s equation (1) establishes the relation between the surface tension of solid, air and liquid as follows:

$$\cos \theta = (\gamma_S - \gamma_{SL}) / \gamma_L \qquad (1)$$

Where γ_S is the surface tension of solid, γ_{SL} the surface tension of liquid interface, and the contact angle (θ) between solid (s) and a liquid (L).

Applying a droplet of a liquid to a flat and isotropic surface, the shape of the droplet depends on the surface tension of the solid and liquid phase, whereby at the contact point in the cross section of the three phases solid-liquid-gaseous the contact angle θ can be measured characterizing the wettability of the solid surface by the applied liquid (Figure 1) (SCHEIKL/DUNKY 1998).

2. MATERIALS AND METHODS

2.1 Remediation of CCA-treated wood particles

CCA-treated (retention: 6.4 kg/m^3) southern yellow pine particles (6-16 mesh in size) were extracted with 0.8% oxalic acid (OA) (Sigma Chemicals, St. Louis, MO) (1:9, w:v) (pH:1.7) for

18 hours at 25°C in polypropylene carboys. In order to bioremediate the particles, OA was siphoned off and 18 L nutrient broth (Difco, Detroit, MI) prepared according to manufacturer's directions, were added and inoculated with 500 mL of an 18-h culture of *Bacillus licheniformis* CC01, a gram-positive spore-forming and copper-tolerant bacterium. This *Bacillus* isolate grows at temperatures ranging from 10°C to 55°C and at pH 3-10 in the nutrient broth (CLAUSEN/SMITH 1998). Carboys were then incubated at 28°C and stirred at 100 rpm for 10 days. Spent medium was siphoned off and bioremediated chips were collected on cheesecloth covered screens and oven dried at 60°C (CLAUSEN 2000; CLAUSEN/SMITH 1998).

2.2 Particleboard manufacturing

Two 406.4 mm square particleboard panels by 6.4 mm thick, with an approximate specific gravity of 0.80, were manufactured per particle type. Eight hundred ninety-nine grams of each of four particle types (control, CCA-treated, OA-extracted and bioremediated) were blended with 10% urea formaldehyde (UF) resin (Southeastern Adhesives' 9-2035, Lenoir, NC, U.S.A.). The UF resin was applied in a rotating drum blender using an atomizing Binks spray gun. Particleboard panels were formed by hot-pressing for 5 min to an internal temperature of 121°C (YOUNGQUIST 1999). The boards were then trimmed to 406.4 by 406.4 mm and conditioned at 20°C and 65% relative humidity (RH) for 2 weeks. Four types of board were manufactured from control (untreated southern yellow pine), CCA-treated southern yellow pine, OA-extracted, and bioremediated CCA-treated southern yellow pine particles.

2.3 Contact angle measurement

Contact angles on surfaces of particleboard samples made from untreated, CCA-treated, OA-extracted, and bioremediated southern yellow pine particles were measured with Rame-Hart, Inc.`s Goniometer, Model 100-100-115 (MALDAS/KAMDEM 1998). The board samples were cut into 20 cm by 4 cm from boards and conditioned at RH of 50% and a temperature of 23°C. The goniometer-icroscope tube was set horizontally. The sample rested on a bracket attached to the stage, and a small droplet (0.05 ml) of liquid was laced on the specimen with a micro-pipette. The contact angle was measured by rotating the microscope eyepiece so that the hairline passed through the point of contact between droplet and sample surface, and tangent to the at that point. The contact angles for 10 droplets on each board sample per liquid were measured at 23°C and 50% RH. The contact angles were recorded at 15 seconds. Table 1 shows the liquids and their surface tension components used for contact angle measurement.

2.3 Water absorption and thickness swelling

Particleboard samples (152.4 by 152.4 mm) were evaluated for water absorption and thickness swelling at 2 and 24-h according to ASTM D 1037-96a test method (ASTM 1999). Water absorbed from the increase in weight during submersion and thickness swelling, as a percentage of the conditioned thickness at 20°C and 65% RH were calculated.

3. RESULTS AND DISCUSSION

The average wettabiliy values and standard deviations, given as contact angle, are shown in Figure 2. The decrease of the contact angle indicates the rate of absorption of water on the particleboard samples. The contact angle formed by distilled water on the control particleboard samples averaged 71 degrees. The contact angle increased in the particleboard samples made from

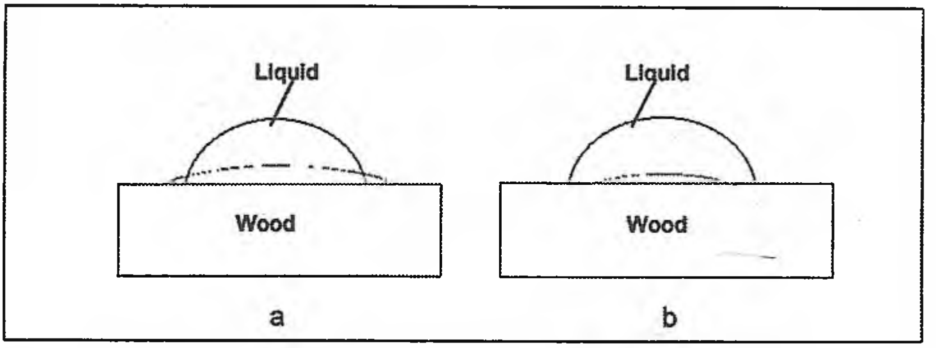

Figure 1: Decrease of the contact angle of droplets applied to a wood surface: (a) the liquid spreads on the surface (wetting), the wetted surface area increases. (b) the liquid penetrates into the wood cell lumens, the wetted surface does not increase (SCHEIKL/DUNKY 1998).

Şekil 1: Odun yüzeyinde sıvı damlacığının temas açısının azalması: (a) sıvı yüzeyde dağılır (ıslanma), ıslanmış yüzey alanı artar. (b) sıvı odunun hücre lümenlerine nüfuz eder, ıslanmış yüzey alanı artmaz (SCHEIKL/DUNKY 1998).

CCA-treated particles to a maximum of about 93 degrees. The average contact angles for particleboard samples made from OA-extracted and bioremediated particles decreased compared to that in particleboard samples containing CCA-treated wood particles. Figure 2 shows that the contact angles of glycerol on the surfaces of particleboard samples made from CCA-treated particles are highest compared to other liquids used in the study. Our results revealed that generally control particleboard samples and particleboard samples containing OA-extracted and bioremediated wood particles exhibited much lower contact angles than particleboard samples made from CCA-treated particles.

Contact angle test results show that the particleboard surfaces containing CCA-treated particles became hydrophobic. On the other hand, untreated wood particles have slightly greater acid-base character than the CCA-treated wood. However, the acid-base character of wood is dominated by electron donating sites on the wood surfaces. The electron donating character of the CCA-treated wood is much less than the untreated wood, and a reasonable explanation for this is because of the acidic character of the CCA components (ZHANG et al 1997).

Water absorption and thickness swelling were reduced by the use of CCA-treated and OA-extracted wood particles (Figure 3 and Figure 4) and closely related (Figure 5). Greater water absorption and thickness swelling values were found in the control particleboard and particleboard samples containing bioremediated wood particles. Percentage water absorption was greater for control particleboard samples (54%) than for particleboard samples made from bioremediated wood particles (49%) after 2-h immersion. In general, composite products containing UF resin are not water resistant (MEYERS 1984) and water absorbing capacity and thickness swelling increases can be expected in control particleboard samples. The relative effect of using CCA-treated particles was greater for water absorption; the use of CCA-treated particles reduced thickness swelling based on control particleboard samples. The particleboard samples made from OA-extracted wood particles also showed resistance to water absorption and thickness swelling even after 24-h. These results indicate that bioremediation of CCA-treated wood particles by *Bacillus licheniformis* culture increased the water absorbing capacity of the remediated particles.

Table 1: Surface tension components (mj/m^2) of liquids used for contact angle measurements

Tablo 1: Temas açısı ölçümleri için kullanılan sıvıların yüzey gerilim komponentleri (mj/m^2)

Liquids Sıvılar	γL	$\gamma^d L$	$\gamma^P L$	$\gamma^{LW} L$	$\gamma^{AB} L$	$\gamma^+ L$	$\gamma^- L$
Ethylene glycol (EG) Etilen glikol	48.0	29.0	19.0	29.0	19.0	1.92	47.0
n-Butanol:water (2:98) n-Butanol:su	49.0	-	-	-	-	-	-
n-Butanol:water (1:99) n-Butanol:su	55.0	-	-	-	-	-	-
Formamide (FA) Formamid	58.0	39.0	19.0	-	19.0	2.28	39.6
Glycerol Gliserol	64.0	34.0	30.0	34.0	30.0	3.92	57.4
Distilled water Destile su	72.8	21.8	51.0	21.8	51.0	25.5	25.5

γL : **Surface tension of liquid**/Sıvının yüzey gerilim değeri
$\gamma^d L$: **Respective dispersion of liquid**/Sıvının bağıl dispersiyon değeri
$\gamma^P l$: **Polar component of liquid**/Sıvının polar komponenti
$\gamma^{LW} L$: **Lifshitz van der Waal component of liquid**/Sıvının asid-baz komponenti
$\gamma^+ L$: **Acid component of liquid**/Sıvının asid komponenti
$\gamma^- L$: **Base component of liquid**/Sıvının baz komponenti

4. CONCLUSIONS

Higher contact angles for particleboard samples made from CCA-treated wood particles compared to other types of particleboard indicated poor wettability of the board surface. It is clear from our results that the board surfaces were hydrophobic in these particleboard samples. Lower wettability of particleboard samples made from CCA-treated wood reflects the physical and chemical affinity between boards surface and a liquid such as adhesive or water. The improved compatibility between CCA-treated particles and UF resin during particleboard manufacturing resulted in board samples containing CCA-treated furnish with improved water resistance and thickness swelling. Although bacterial fermentation somewhat increased the water absorbance capacity, thickness swelling, and wettability, OA-extraction may be useful for cleaning of wood particles containing chromium, copper, and arsenic elements.

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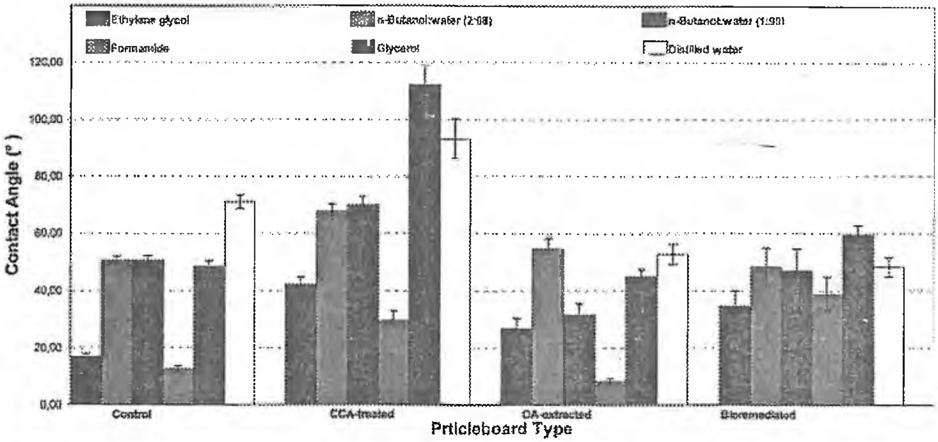

Figure 2 : Average contact angles of liquids on different types of particleboard samples
Şekil 2 : Farklı tiplerdeki yongalevha örnekler üzerinde sıvıların ortalama temas açıları

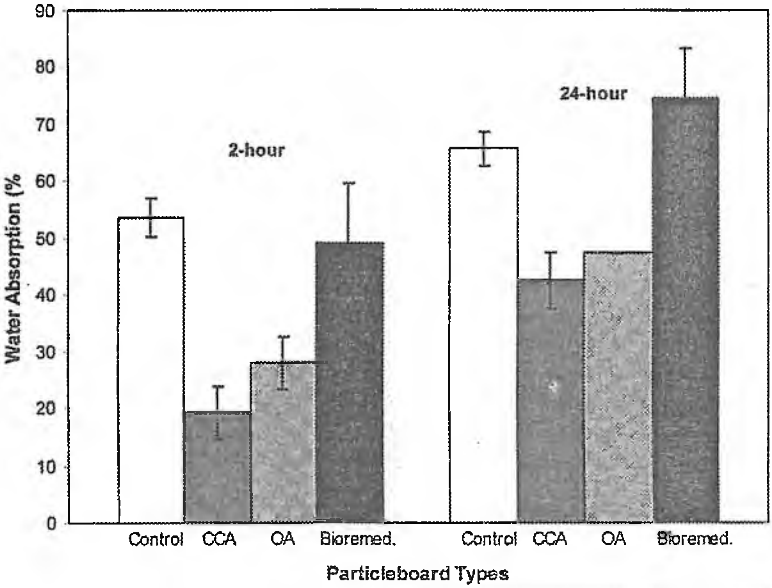

Figure 3: Water absorption of particleboard samples after 2 and 24-h immersion.
Şekil 3 : Yongalevha örneklerinde 2 ve 24 saat sonra su absorpsiyon miktarları

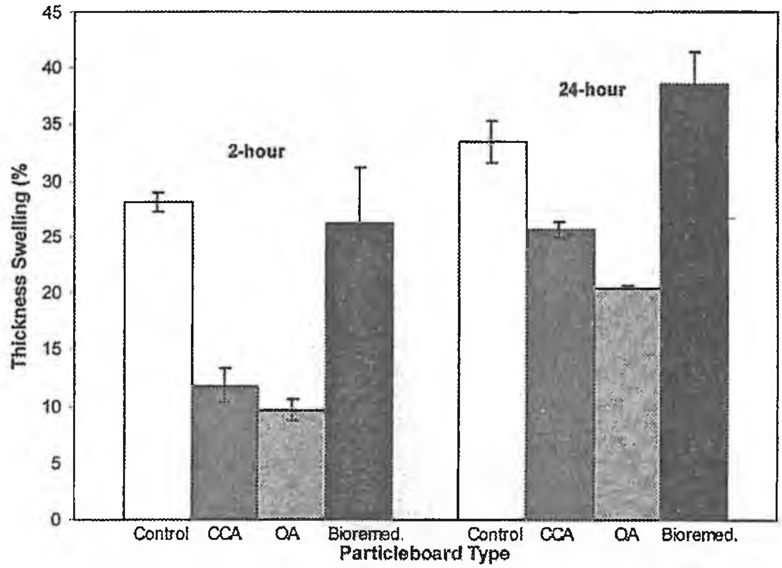

Figure 4: Thickness swelling of particleboard samples after 2 and 24-h immersion.

Şekil 4 : Yongalevha örneklerinde 2 ve 24 saat sonra kalınlığına şişme miktarları

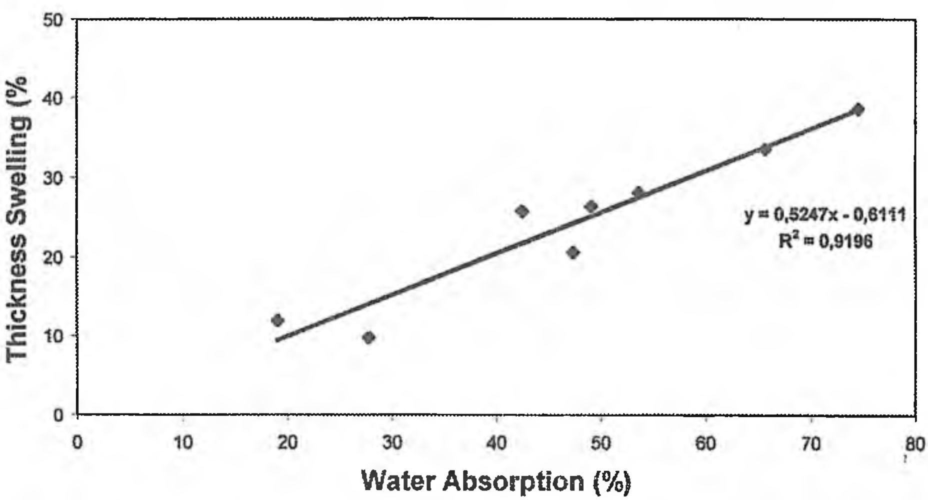

Figure 5: Thickness swelling and water absorption relationship from2 and 24-h water soaking at room temperature. Line shows a linear fit of the data.

Şekil 5 : 2 ve 24 saat sonra örneklerde kalınlığına şişme ve su absorpsiyonu arasındaki doğrusal ilişki.

CCA İLE EMPRENYE EDİLMİŞ VE GERİ KAZANILMIŞ ODUNDAN YAPILAN YONGALEVHALARDA ISLANABİLİRLİK, SU ABSORPSİYONU VE ŞİŞME

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Kısa Özet

Kompozit materyal üretimi, CCA (bakır, krom, arsenik) ile emprenye edilmiş ve geri kazanılmış odun için en iyi alternatiflerden biridir. Bu çalışmada kontrol, CCA ile emprenye edilmiş, okzalik asid (OA) ile extracte edilmiş ve biyolojik geri kazanıma uğramış odunlardan üretilen yonga levhalarda yüzeylerin ıslanabilirliği, su absorpsiyonu ve kalınlığına şişme değerleri belirlenmiştir. Islanabilirlik, su absorpsiyonu ve kalınlığına şişme değerlerinin CCA ile emprenye edilmiş odundan yapılan levhalarda azaldığı belirlenmiştir. Bununla birlikte *Bacillus licheniformis* kullanılarak biyolojik geri kazanıma uğramış odunun, yonga levhaların bu özelliklerinde olumsuz etkiler yaptığı sonucuna varılmıştır.

ÖZET

Emprenye edilmiş ve geri kazanılmış odundan kompozit materyal yapımı en uygun alternatiflerden birisidir. Bu tip geri kazanılmış malzeme lif levha, yonga levha ve çimentolu yonga levha gibi levha ürünlerinin üretimi için iyi bir potansiyal oluşturmaktadır. Bu konuda yapılan çalışmalar bu tip levha ürünlerinin bazı özelliklerinde, emprenye maddesi ve kullanılan tutkal arasındaki etkileşimden dolayı azalmalar olduğunu göstermektedir (MUNSON/KAMDEM 1998). Emprenye maddesi etkileşimini indirgemek amacıyla geliştirilen asid ekstraksiyonu ve biyolojik geri kazanım metodları emprenye edilmiş atık odundaki bakır, krom ve arsenik elementlerinin önemli bir kısmını uzaklaştırabilmektedir.

Katı bir yüzeyin ıslanabilirliği, malzeme ile sıvı arasındaki temas açısı olarak tanımlanmakta ve küçük temas açıları daha yüksek ıslanabilirliği göstermektedir (ADAMSON 1982). Temas açısı, ağaç türü, ekstraktif maddeler, anatomik özellikler, rutubet miktarı, bağıl nem, sıcaklık vb. faktörlere ve kullanılan sıvıya bağlı olarak değişkenlik göstermektedir. Kompozit materyallerde tutkallanma kalitesi odunla tutkalın teması ile etkilendiğinden, ıslanabilirlik oldukça önemlidir. Geri kazanılmış ve CCA içeren odundan yapılan kompozit materyallerde tutkal ve CCA içeren odun arasında iyi bir bağlanma temin etmek için, odun yüzeylerindeki bu etkileşimin iyi anlaşılması gerekmektedir.

Bu çalışmada önceden 6.4 kg/m^3 retensiyonda CCA-C emprenye maddesi ile emprenye edilmiş odundan elde edilen yongalar %0.8 okzalik asit ile 25°C de 18 ssat süreyle ekstrakte edilmiş ve emprenye maddesi aktif elementleri yıkanıma uğratılmıştır. Bu yongalar daha sonra 28°C de *Bacillus licheniformis* bakteri fermantasyonu ile işleme sokulmuştur. Elde edilen yongalardan ve kontrol yongalarından üre formaldehid tutkalı kullanılarak yonga levhalar elde edilmiştir.

KALDAS ve KAMDEM 1998'e yonga levhalar üzerinde göre temas açıları belirlenerek levhaların ıslanabilme özellikleri bulunmuştur. Ayrıca ASTM standardlarından yararlanılarak levhaların su absorpsiyon ve kalınlığına şişme değerleri incelenmiştir.

CCA ile emprenye edilmiş yongalardan yapılan levhalarda temas açıları diğer tip levhalar ile karşılaştırıldığında yüksek bulunmuştur. Bu tip levhaların yüzeylerinin daha hidrofobik olduğunu temas açılarının yüksek olması göstermektedir. OA-ekstraksiyonunun ve biyolojik fermantasyonun temas açıları üzerinde olumsuz etkileri olduğu belirlenmiştir. Bunun yanında su absorpsiyon ve kalınlığına şişme değerleri için CCA ile emprenye edilen ve OA-ekstraksiyonu uygulanan odundan yapılan levhalarda diğer tip levhalara karşı iyileşmeler olduğu tespit edilmiştir. Araştırma sonuçları, CCA ile emprenye edilmiş odundan bakır, krom ve arsenik elementlerinin uzaklaştırılması amacı ile uygulanan *Bacillus licheniformis* bakteri fermantasyonunun odunun su absorbe etme kapasitesini artırdığını göstermiştir.

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