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Determination of Some Physical Properties of Oil Heat Treated Oriental Beech Wood

Yağlı Isıl İşlem Uygulanmış Doğu Kayını Odununun Bazı Fiziksel Özelliklerinin Belirlenmesi

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Abstract

In this study, some physical properties of wood heat treated with vegetable oil were examined. In the study, Oriental Beech (*Fagus Orientalis* L.) wood was used as the testing material and corn oil was used as the vegetable-based oil. In the study, oil heat treatment temperatures and times were carried out at 150 ˚C and 210 ˚C for 2.5 hours and 5 hours, respectively. After oil heat treatment, the physical properties of the wood samples, such as oven-dry and air-dry density and water uptake percentages, were detected according to TS ISO 13061-2 2472 standard. According to the data obtained, the oven-dry and air-dry densities of the oil heat treated samples increased compared to the control samples. Among the oil heat treated samples, the highest oven-dry density value was determined in the samples heat treated at 150 ˚C for 2.5 hours. Besides; Among the oil heat treated samples, the highest air dry density value was obtained in the samples heat treated at 210 ˚C for 2.5 hours. In the study, according to the water uptake test results, oil heat treated samples had lower water uptake compared to control samples. Additionally, after a 120-hour water uptake period; While the lowest water uptake, 49.94%, was determined in the samples subjected to oil heat treatment at 150 ˚C for 5 hours, the highest water uptake was determined in the control samples, with 80.51%. In summary, the oil heat treatment method with corn oil was effective in reducing water uptake of wood material.

Keywords: Oil heat treatment, physical properties, oriental beech wood, corn oil

Özet

Bu çalışmada bitkisel yağ ile yağlı ısıl işlem uygulanmış odunun bazı fiziksel özellikleri incelenmiştir. Çalışmada deneme materyali olarak Doğu kayını (*Fagus Oriental*is L.) odunu ve bitkisel esaslı yağ olarak mısırözü yağı kullanılmıştır. Çalışmada yağlı ısıl işlem sıcaklık ve süreleri sırasıyla 150 ˚C ve 210 ˚C'de 2,5 saat ve 5 saat olarak gerçekleştirilmiştir. Yağlı ısıl işlem uygulamasından sonra ahşap örneklerinin TS ISO 13061-2 2472 standardına göre tam kuru ve hava kurusu yoğunluğu ve su alma yüzdeleri gibi fiziksel özellikleri tespit edilmiştir. Elde edilen verilere göre yağlı ısıl işlem uygulanan örneklerin tam kuru ve hava kurusu yoğunlukları, kontrol örneklerine göre artış göstermiştir. Yağlı ısıl işlem gören örnekler arasında en yüksek tam kuru yoğunluk değeri 150 ˚C'de 2.5 saat ısıl işlem gören örneklerde belirlenmiştir. Bunun yanında; yağlı ısıl işlem gören örnekler arasında en yüksek hava kurusu yoğunluk değeri 210 ˚C'de 2.5 saat ısıl işlem gören örneklerde elde edilmiştir. Çalışmada, su alma testi sonuçlarına göre, yağlı ısıl işlem gören örneklerde kontrol örneklerine kıyasla daha düşük su alımı gerçekleştirmiştir. Ayrıca 120 saat su alma periyodu sonrası; en düşük su alımı %49.94 ile 150 ˚C'de 5 saat yağlı ısıl işlem gören örneklerde belirlenirken, en yüksek su alımı %80.51 ile kontrol örneklerinde tespit edilmiştir. Özetle mısır özü yağı ile yağlı ısıl işlem yöntemi ağaç malzemenin su emilimini azaltmada etkili olmuştur.

Anahtar Kelimeler: Yağlı ısıl işlem, fiziksel özellikler, doğu kayını odunu, mısır özü yağı

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1. Introduction

Wood material have been used and in demand since the earliest periods of history. It is a biologically sustainable material that is still used in many sectors today. It is used both indoors and outdoors as a building element and decoration element. Wood material; In addition to many positive features such as natural, organic, wide color, texture and size variety, superior aesthetic and acoustic properties, recycling feature, not causing any harm to the environment in terms of production, thermal insulation and being a renewable resource compared to other materials, it also has some negative features (Gökmen, 2017). Various methods have been developed to eliminate these negative features These methods; acetylation, methods made with various chemicals, mechanical methods (such as plywood production), protective methods applied only to the upper surface are grouped under many titles (Epmeier et al., 2004). However, impregnation methods used to increase the biological strenght of solid wood material and chemicals with toxic content used in this field have begun to give way to environmentally friendly methods due to the damage they cause to the environment today.

Nowadays, some heat treatment methods have begun to be used more frequently instead of these methods. While applying these methods, hot air, water vapor, an inert gas (nitrogen gas) or hot oil are used as heat carriers. Oil Heat Treatment (OHT) applied in Germany is a method that uses vegetable oil. It is a technique that distinguishes itself from others with this feature. OHT, a combination of heat treatment and oil impregnation, has emerged as a necessary method to improve the properties of wood material (Sailer et al., 2000). After heat treatment, while there is a weight loss in wood material in other methods, it has been reported that weight gain occurs in the OHT method due to the oil uptake of the wood. The color of the wood darkens and its smell changes. It is easier to process with machines. Its biological durability increases (Epmeier et al., 2004; Korkut and Kocaefe, 2009). Industrial vegetable oils used for heat treatments include flaxseed, rapeseed, palm, soybean and coconut (Welzbacher and Rapp, 2005; Wang and Cooper, 2005). Considering that many vegetable oils have boiling points higher than 260°C, some of them may be appropriate as heat transfer medium for thermal modification (Gunstone, 2002). Wood products' improved qualities are the result of chemical changes in the wood, and the degree of these changes is contingent upon the temperature, processing time, and type of wood used (Hill, 2007). Vegetable oils such as sunflower, palm, coconut, soybean and rapeseed oil are non-toxic and relatively affordable. Oils that do not break down when exposed to oxygen in the atmosphere can oxidize, creating a protective layer on the wood material (Hyvonen et al, 2007; Temiz et al, 2008).

Furthermore, as the mass loss in wood material increases, the density and equilibrium moisture content of the wood material decrease and it absorbs less water (Bal, 2013; Esteves and Pereira, 2009). In studies conducted according to the OHT method in hot oil; At the end of the process, weight gain occurs due to fat uptake. In the OHT method, as the processing temperature increases, the weight gain (oil uptake) decreases (Sailer et al., 2000; Kumar et al., 2012; Sidorova 2008). The increase in water repellency during the oil refining stage does not only depend on the properties and type of the oil. In addition, it depends on the processing time, the refining temperature of the oil and the rate of oil retained in the wood. Longer processing times, higher processing temperatures and greater oil retention increase water repellency (Wang and Cooper, 2005). In the study conducted by Can and Sivrikaya, (2016) it was found that fir samples impregnated with tall oil took 38.58% less water in the 72 hours water uptake tests of the impregnated samples. In parallel with the increase in Tall oil concentration, water uptake decreased. In addition, in this study, the formation of an emulsion of tall oil with water showed more effective results (Can and Sivrikaya, 2016). The water-repellent activity of oils is parallel to the oil concentrations in wood. Better water-repellent effectiveness is achieved by increasing the concentration in oil treatment, which reduces water uptake by filling the cell gaps. Similar results have been revealed in literature studies. 74%-86% water repellent effectiveness was achieved in oil impregnation processes (Sivrikaya et al., 2016). Hofland and Tjeerdsma (2005) and Hyvonen et al. (2005) found that heat treatment of wood with tall and rapeseed oils reduced water uptake. It can be explained that, as a non-swelling chemical material, the molecule size of flaxseed oil is too large to penetrate the cell wall. Therefore, during the oil absorption phase, most of the oil is located in the cell lumen (Hill, 2007). It has been determined that when the oils dry during heat treatment, they form an outer shell and this water-repellent oil penetrates into the wood. (Wang, 2007). Bal, (2016) treated Taurus fir wood with hot vegetable oil at temperatures of 160 ºC, 180 ºC, 200 ºC and 220 ºC. After the process, some physical properties of the wood such as weight gain, density, tangential swelling, radial swelling and volumetric swelling were determined. According to the findings; It has been determined that weight gain and other physical properties decrease as temperature increases. Bal and Ayata (2021) examined poplar (*Populus nigra*) wood samples at 180 ºC, 200 ºC and 220 ºC heat treatment in vegetable oil for 2 hours. Then, the effects of heat treatment on water uptake percentages were examined. According to the data obtained, it was determined that the percentage of water uptake decreased in all heat-treated samples compared to the control group.

In this study, it was aimed to determine the air and oven-dry densities and water uptake changes of Oriental Beech wood subjected to oil heat treatment using vegetable oil (corn oil). In addition, comparison results regarding the physical properties of wood subjected to oil heat treatment and those of untreated wood were made, as well as an evaluation of the effect of the applied treatment on these properties. As a result of this evaluation, it is aimed to both extend the lifespan of wood and contribute to the country's economy and nature by reducing the water absorption of wood materials used especially in outdoor weather conditions.

2. Materials and Methods

2.1. Materials

Preparation of wood samples

In study, Oriental Beech (*Fagus orientalis* L.) wood was chosen as the test material. These wood samples were obtained as first class material from the timber yard exposed to natural drying conditions. Furthermore, in providing samples, sapwood parts were selected that were free of knots, cracks, smooth fibers, and not damaged by fungi or insects. For oven and air-dry densities and water uptake tests, Oriental Beech samples were cut radially, tangentially and longitudinally into rectangles of 20 mm x 20 mm x 20 mm.

Vegetable Oils

Corn oils were utilized as vegetable oils in this investigation. Oil extracted from the wheat germ of maize is known as corn oil. In general, corn oil is cheaper than many other vegetable oils. Corn oil is also a key element used in making biodiesel. Corn oil has other industrial uses in the production of soaps, ointments, paints, textiles, nitroglycerin, rust inhibitors for metal surfaces, and insecticides. Corn oil contains 56% polyunsaturated fat, 31% monounsaturated fat and 13% saturated fat. In addition, corn oil contains high amounts of polyunsaturated fatty acids instead of saturated fats (Anonymous, 2024).

2.2. Methods

Treatment process

The samples were dried in an oven at 103 °C ± 2 °C until they reached a consistent weight in preparation for oil heat treatment. After this period, samples were transferred and immersed in a heated oil bath at 150 °C, and 210 °C for 2.5 h, and 5 h at each defned temperature, respectively. During heat treatment of samples, the oil bath was covered and after the oil heat treatment, the samples were wiped and cooled (Hao et al., 2021).

Oven-dry density test

The oven-dry density of the test samples was applied according to the TS ISO 13061-2 2472 (TS ISO, 2021) standard. It was necessary to dry the test samples at 103 °C ± 2 °C until they attained a consistent weight. After allowing the samples to cool, their diameters were measured using a fine calliper with a resolution of 0.01 mm, their volumes were approximated using the stereo metric method, and their weights were recorded on an analytical balance with a possible 0.01 g. Then, the oven-dry density values of the samples were determined using formula 1.

$$\delta_0=\frac{MO}{VO}(g/cm^3) \quad (1)$$

In this section;

δ_0= Oven-dry density (g/cm^3)

M_0 = Oven-dry weight of samples (g)

V_0 = Oven-dry volume of samples (cm^3)

Air-dry density test

The air-dry density values of the test samples were computed using TS ISO 13061-2 2472 (TS ISO, 2021). Test samples were maintained in the cabinet at 65% relative humidity and 20°C until they stabilized in weight. The dimensions were measured with a caliper with an accuracy of 0.01 mm, the volumes were computed using the stereometric method, and the air-dry density was computed. All of these measurements were made using an analytical balance. Formula 2 was used when calculating air-dry density values.

$$\delta_{12}=\frac{M12}{V12}\ (g/cm^3) \quad (2)$$

In this formula;

δ_{12}= Air-dry density (g/cm^3)

M_{12} = Air-dry weight of wood samples (g)

V_{12} = Air-dry volume of wood samples (cm^3)

Water uptake test

In a room environment, the samples were held in distilled water for 2, 8, 24, 48, 72, 96 and 120 hours, respectively. After each soaking interval, samples were removed from the water, patted dry with paper, and then weighed. As a result, the WA of each sample was calculated using formula 3.

$$W_A=\frac{W2-W1}{W1}x100 \quad (4)$$

In this section;

W_A= Water uptake (%),

W_2 = Wet weight of the wood samples after wetting with water (g),

W_1= Initial dry weight (g)

Statistical evaluation

After the test results were acquired, the SPSS computer assessed the variance analysis and Duncan test, which was covered at a 95% confidence level. Homogeneity groups (HG) were subjected to statistical analyses, where different letters denote statistical significance.

3. Results and Discussions

3.1. Oven-dry density test

The oven-dry density values of corn oil heat treated Oriental Beech samples are given in Table 1.

Table 1. The oven-dry density values of the Oriental Beech samples.

Samples	Oven-dry density (g/cm^3)	Standard deviation	Homegeneity groups	Increase compared to control samples (%)
Control	0.661	0.05	A	-
150 ˚C/2.5 hours	0.832	0.04	C	+25.90
150 ˚C/5 hours	0.746	0.05	B	+12.60
210 ˚C/2.5 hours	0.795	0.02	C	+20.30
210 ˚C/5 hours	0.803	0.03	C	+21.48

The oven-dry density values of corn oil heat treated wood were increased compared to the control samples. While the minumum oven-dry density values were obtained in control samples (0.661 g/cm^3), the maximum oven-dry density value was detected in samples that were oil heat treated at 150 ºC for 2.5 hours (0.832 g/cm^3). A statistically significant difference was found between the control samples and the oil heat treated samples at 95% confidence interval. While the oven-dry density values of the samples decreased as the heat treatment time increased in the samples subjected to oil heat treatment at 150 ºC, the oven-dry density values of the samples increased as the heat treatment time increased in the samples subjected to oil heat treatment at 210 ºC. Var et al. (2021) sought to ascertain the oven-dry density values of Red pine treated with hot-cold bio-oil. The findings showed that the test samples' densities rose by 40,38 % to 78,85 %. In our study, the findings we obtained due to the oil heat treatment method increasing the oven-dry density value of the samples are similar to those of Var et al. (2021) is consistent with. Okon et al. (2018) found that the oven-dry density of Cunninghamia lanceolata wood heated with oil increased to 75 % during the first stage of treatment due to oil uptake, but then decreased as the temperature and treatment time increased. They clarified that the decrease in density is caused by the pyrolysis and degradation of the cell wall polymers during oil heat treatment. In our study, the oven dry density value of the samples subjected to oil heat treatment at 150 ºC for 2.5 hours first increased compared to the control, and then as the heat treatment time increased, the oven- dry density values decreased. In summary, the findings we obtained from samples subjected to oil heat treatment at 150 ºC are consistent with Okon et al. (2018) supports the findings. Var and Demir (2020) aimed to determine the oven and air dry densities effect of hot-cold bio-oil process on wood material prepared from red pine wood. In the study, castor oil (*Ricinus communis* L.), linseed oil (Oleum linii), mixed oil (castor oil + linseed oil) and red pine (*Pinus brutia* Ten.) sapwood were used. Wood samples were treated with hot (110 ºC ± 2 ºC) oil for 6 hours and then cold (23 ºC ± 2 ºC) oil for 2 hours. According to their results, the density of the test samples increased by 40.38%-78.85% compared to the control. Dubey et al. (2016) revealed that the density of *Pinus radiata* wood after heat treatment with oil was at a higher level than the untreated control group. In the results found from our study, our results were compatible to the results obtained by Var and Demir (2020) and Dubey et al. (2016), as the oil heat-treated samples gave higher oven-dry density values than the control samples.

3.2. Air-dry density test

The air-dry density values of corn oil heat treated Oriental Beech samples are given in Table 2.

Table 2. The air-dry density values of the Oriental Beech samples.

Samples	Air-dry density (g/cm^3)	Standard deviation	Homegeneity groups	Increase compared to control samples (%)
Control	0.654	0.04	A	-
150 °C/2.5 hours	0.803	0.03	B	+22.80
150 °C/5 hours	0.806	0.04	B	+23.20
210 °C/2.5 hours	0.840	0.04	B	+28.40
210 °C/5 hours	0.801	0.05	B	+22.50

When compared to the control samples, the samples that underwent oil heat treatment with maize oil had higher air-dry density values. The samples that underwent oil heat treatment at 210 ºC for 2.5 hours had the maximum air-dry density value of 0.840 g/cm^3, whereas the control samples had the minumum air-dry density values (0.654 g/cm^3).. Between the oil heat-treated samples and the control samples, a statistically significant difference was discovered at 95% confidence interval. While the air-dry density values of the samples increased as the heat treatment time increased in the samples that were oil heat treated at 150 ºC, the air-dry density values of the samples decreased as the heat treatment time decreased in the samples that were oil heat treated at 210 ºC. In addition, no statistically significant difference was found between the oil heat treated samples. Bayraktar and Pelit (2022) applied the oil treatment method with linseed oil to Scots pine (*Pinus silvestris* L.) and Beech (*Fagus sylvatica* L.) wood samples and subjected them to heat treatment at 3 different temperatures (170 °C, 190 °C and 210 °C). According to the research results, the air-dry density of oil heat treated samples increased compared to control samples. Var and Demir (2020) aimed to determine the oven and air dry densities effect of hot-cold bio-oil process on wood material prepared from red pine wood. In the study, castor oil (*Ricinus communis* L.), linseed oil (Oleum linii), mixed oil (castor oil + linseed oil) and red pine (*Pinus brutia* Ten.) sapwood were used. Wood samples were treated with hot (110 ºC ± 2 ºC) oil for 6 hours and then cold (23 ºC ± 2 ºC) oil for 2 hours. According to their results, the density of the test samples increased by 40.38%-78.85% compared to the control. In the results obtained from our study, our results were compatible to the results obtained by Bayraktar and Pelit (2022) and, Var and Demir (2020), as the oil heat-treated samples gave higher oven-dry density values than the control samples.

3.3. Water uptake test

The water uptake values of the Oriental beech samples oil heat treated with corn oil are given in Table 3 and Figure 1.

Table 3. The water uptake values of the Oriental Beech samples.

Samples	Water uptake values (%)													
	After 2 hours	H.G.	After 8 hours	H.G.	After 24 hours	H.G.	After 48 hours	H.G.	After 72 hours	H.G.	After 96 hours	H.G.	After 120 hours	H.G.
Control	42.65	B	53.95	C	59.92	B	64.88	B	72.89	C	77.61	B	80.51	B
150 ˚C/2.5 hours	21.25	A	31.39	B	37.49	A	43.06	A	48.69	B	53.36	A	54.85	A
150 ˚C/5 hours	16.26	A	25.60	A	33.74	A	39.51	A	39.67	A	48.68	A	49.94	A
210 ˚C/2.5 hours	17.66	A	26.97	AB	34.04	A	38.61	A	44.28	AB	49.33	A	51.05	A
210 ˚C/5 hours	18.52	A	28.66	AB	35.89	A	39.55	A	44.86	AB	48.83	A	50.03	A

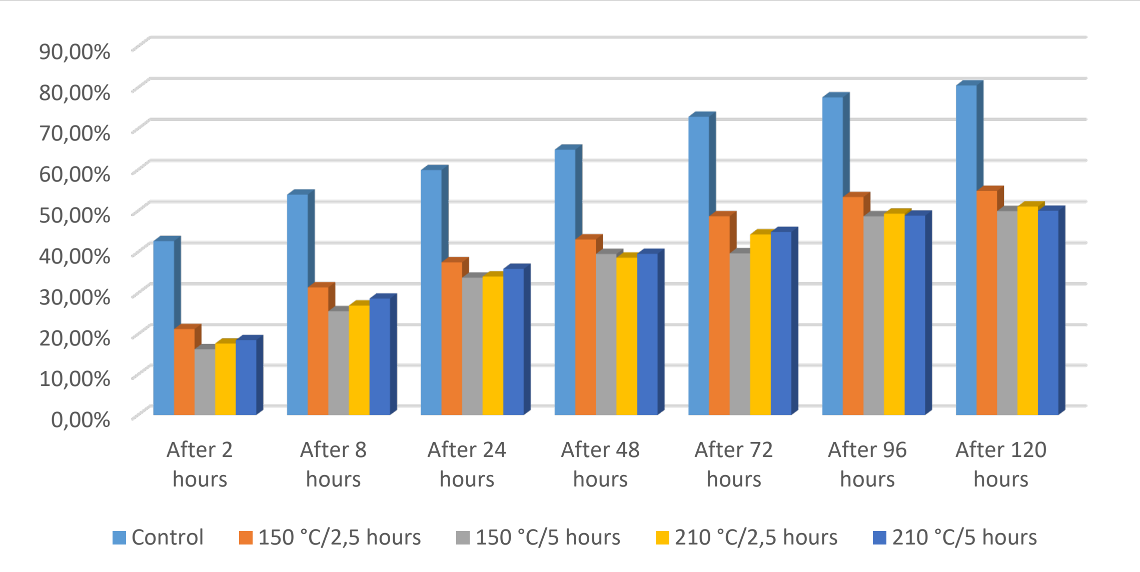

Figure 1. The water uptake rates.

During all water uptake periods, control samples absorbed more water than the samples treated with corn oil. In addition, a statistically significant difference was observed between the control samples and the oil heat-treated samples at all water uptake periods, with a 95% confidence interval. It is well known that oil heat treatment is effective in improving the dimensional stability of wood (Lee et al., 2018). Among the oil heat treated samples, the highest water uptake in all periods was determined in the oil heat treated samples at 150 ºC for 2.5 hours. In addition, no statistically significant difference was found between the samples treated with oil heat traeted after all other water uptake periods except after the 72-hours water uptake period. After the 72-hours water uptake period, a statistically significant difference was detected between the samples treated with oil heat treatment for 2.5 hours at 150 ºC and the samples treated with 5 hours at 150 ºC oil heat treatments. After the 120-hour water uptake period, the water uptake rate of the control samples reached 80.51%. Furthermore, the lowest water uptake rate, 49.94%, was determined in the samples subjected to oil heat treatment at 150 ºC for 5 hours. The water uptake rates of oil heat treated samples decreased between 31.87% and 37.97% compared to the control samples. Kaya, (2023) impregnated wood samples with linseed oil (LO). The heat treatment was applied in the oven at four different temperatures: 160, 180, 210 and 240 ˚C, respectively. He found that the physical properties (water uptake) of the treated wood decreased by 72% as compared to the control group. Taşdelen et al. (2019) found that water uptake for oil heat-treated samples decreased compared to untreated samples. Salim et al. (2010) reported that heat treatment of crude palm oil for bamboo reduced hygroscopicity. It has been reported that the equilibrium moisture (Bak and Nemeth, 2012) and water uptake (Bazyar, 2012) of poplar wood subjected to linseed oil heat treatment are lower than untreated wood. In our study, our findings were similar to the literature, as the water uptake rate of oil heat treated samples decreased compared to control samples. As oil time and temperature increase, dry shrinkage gradually decreases. The reason for this may be the loss of water uptake regions and the decrease in the number of O–H and C=O groups (Yin et al., 2011). In our study, oil heat treatment time and temperature did not affect the water uptake of the samples. Tang et al. (2019) found that after oil heat treatment with tung oil, the oil was well distributed in bamboo lumens and cell walls, and the dimensional stability increased. Mastouri et al. (2021) investigated the water uptake rates of oriental cotton (*Populus deltoides*) wood subjected to oily heat treatment with silicone and rapeseed oil at 190 °C for 4 h. Their results showed that oil heat treatment reduced the water absorption of the samples. Our findings are consistent with Tang et al. (2019) and Mastouri et al. (2021) is consistent with the findings.

4. Conclusions

In this study, the physical properties of Oriental beech wood, which was heat treated with corn oil were examined, such as air-dry and oven-dry densities and water uptake tests. According to the findings obtained from this study, the oil heat treatment with corn oil was effective in increasing the oven-dry and air dry densities of the samples. According to the oven-dry density data, the highest density increase occurred in the oil heat treated samples at low temperatures and low times. In addition, in the study, the air-dry density of the samples heat treated with corn oil increased between 12.60% and 25.90% compared to the control samples. According to air-dry density data, the highest density increase was detected in oil heat-treated samples at high temperatures and low times. In this study, the air-dry density of the samples heat treated with corn oil increased by 22.50% to 28.40% compared to the control samples. According to the water uptake test results, the oil heat treatment method with corn oil was effective in reducing the water uptake of the samples in all water uptake periods. According to the results of the study, camellias, benches, sitting tables, etc. It may be recommended to use corn oil and oil heat treatment to reduce water uptake and high density of wood materials used for outdoor use.

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