Determination of Some Wood Properties and Response to Weathering of *Citrus limon* (L.) Burm Wood

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The ability of *Citrus limon* (L.) Burm wood to be used for flooring applications was considered in this work. Selected wood properties were determined, and the response to weathering was tested. Janka hardness, density, screw withdrawal resistance, color, glossiness, and artificial weathering (144, 288, and 432 h) were determined. The wood from *Citrus limon* was shown to be a dense wood with air density around 830 kg/m^3 and with a high Janka hardness of 138.0 N/mm^2, 120.4 N/mm^2, and 115.9 N/mm^2 for cross, tangential, and radial sections, respectively. This opens good perspectives to this kind of wood being used for flooring. Statistical analysis showed that both Janka hardness and screw withdrawal resistance were significantly different between surfaces. Nevertheless, the homogeneity groups showed that the main differences were between the surfaces in the longitudinal direction when compared with the transverse direction. The wood is lighter than most common woods and it is mainly yellow. After weathering, the wood became darker, redder, and yellower. Glossiness decreased in the first hours of the weathering period.

Keywords: Lemonwood; Weathering; Color; Gloss; Janka hardness

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INTRODUCTION

The lemon tree *Citrus limon* (L.) Burm is a member of the Rutaceae family that consists of approximately 140 genera and 1,300 species (Yilmaz and Güneser 2017). *C. limon* is planted for its fruit, which is one of the most known fruits all over the world. Turkey is a big producer of this fruit, amounting to a total of 710,400 tons/year of lemons. According to Yildirim *et al*. (2010), the major lemon producing areas are located in Turkey's east Mediterranean plains and mainly coastal parts along the Cukurova region. In this region the main producers are located in Mersin and Adan, and the region accounts for almost 98% of the lemons produced in Turkey (Yildirim *et al*. 2010).

There is a lot of information about the fruit from the *Citrus limon* tree; however, there is little information about the wood. This might be one of the biggest problems in marketing this kind of wood, because its properties are not well known by consumers. The knowledge of some technological properties might be useful when exploring new uses for this kind of wood, such as flooring, as an example. Recently Berti *et al.* (2018) studied the possibility of using orange wood, which is also a member of the Rutaceae family, for flooring applications. These authors concluded that this kind of wood has excellent technical characteristics to be used as wood flooring and that the aesthetic characteristics were appreciated by professionals and end users.

According to Fang *et al*. (2012), the professional associations, such as the National Wood Flooring Association (NWFA) and flooring manufacturers, rank the wood species by their Janka hardness. They also report that architects usually prefer tropical hardwoods due to their high densities. Nevertheless, the decreased availability of these tropical woods leads wood engineers to look for alternative wood materials.

The most used wood for flooring worldwide is oak, probably due to its high density and hardness but also due to its aesthetic look. There are several oak species, but most of them have high hardness. For instance, Uzcategui *et al*. (2000) studied two different oaks, red oak and white oak and concluded that Janka hardness was 6300 N and 6600 N in tangential surface and 5800 N and 5900 N in radial surface, respectively. Meier (2015) presented the Janka hardness of 16 different species of oak and reported a Janka hardness ranging from 4720 N to 7310 N.

Another important property in wood is its color, which significantly affects its aesthetic look. Architects often choose wood species based on their color, and generally whiter colors are preferred. This has been reported in the work of Wahl (2000), where Japanese consumers stated that light color was preferred in wood floorings. Another advantage of light colored woods is that they can become darker by using a stain or varnish, while darker woods cannot become lighter.

Weathering is important when wood is exposed outside. The first changes to be noticeable are the changes in color. Initially darker woods become lighter, whereas lighter woods become darker and later on, both acquire a similar gray tone, which has been attributed to residual cellulose and fungal growth such as that of *Aureobasidium pullulans* (Kucuktuvek *et al*. 2017). Chemically, the wood polymer most sensible to weathering is lignin, which suffers photochemical damage by UV light, further exposing cellulose and hemicelluloses and leading to their degradation. The mechanical damage of the surfaces can be due to rain, hail, or wind but mostly is owed to shrinkage and swelling of wood.

The goal of this study was to determine some wood properties (screw withdrawal resistance, Janka hardness, glossiness, color properties, and physical properties) and examine the response to artificial weathering of *Citrus limon* wood grown in Mezitli-Mersin, Turkey.

EXPERIMENTAL

Materials

Wood boards of *Citrus limon* (L.) Burm were obtained from a timber company (Erdem Odun - Kömür) located in Mersin, Turkey.

Methods

Determination of physical properties

Equilibrium moisture content and air-dried density were determined following TS 2471 (1976) and TS 2472 (1976), respectively. Ten samples were tested.

Determination of Janka hardness

The samples were cut to 5 cm × 5 cm × 5 cm, totalizing 10 samples, for testing the Janka hardness. On these cut wood materials, the Janka hardness values of tangential, cross, and radial surface were made according to the TS 2479 (1976) standard (Fig. 1A).

Fig. 1. Instruments used for different property measurement: (A) Janka hardness, (B) screw withdrawal resistance, (C) QUV weathering tester, (D) gloss meter, and (E) spectrophotometer

To determine the measurements, 10 test samples were prepared. The Janka Hardness H_j (N) was determined using Eq. 1,

$$H_j = K \times P_{\max} \text{ (N/mm}^2\text{)} \quad (1)$$

where $P_{\max}$ is the load (N) during the insertion of the loading tip into a certain depth within the test piece. The coefficient K is defined by whether the loading end reaches a depth of 5.64 mm, in which case it equals 4/3, and if it reaches 2.82 mm depth, then it is equal to 1. In this study, K values for each group were taken as 1 because there was no cracking in the test samples.

Determination of screw withdrawal resistance

Screw withdrawal resistance of the samples on the tangential, cross, and radial surface was performed following the TS EN 13446 (2005) standard. In this study, screws with dimensions of 4 mm x 50 mm were used. The screw was introduced on the wooden material 20 mm (Fig. 1B) and pulled back to determine the screw withdrawal resistance on wood.

The strength was calculated by the Eq. 2 given below,

$$f = F_{\max} / (d \times l_p) \quad (2)$$

where f is the screw withdrawal resistance (N/mm^2), l_p is the entrance depth (mm), d is the diameter given by the manufacturer (mm), and $F_{\max}$ is the maximum load (N). Ten replicates were used

Artificial weathering

Ten wood samples were exposed in a QUV weathering tester (Q-Lab, Corporation Westlake, USA) (shown in Fig. 1C) following the ASTM G154-06 (2006) standard that is comprised of 8 h ultraviolet exposure, 18 min water spray with 0.75 W/m^2 light intensity, and 50 °C temperature using UV-A 340 nm. This cycle was repeated for a period of 144, 288, and 432 h.

Determination of glossiness measurement

Glossiness parallel (//) and perpendicular (⊥) to grain at 20°, 60°, and 85° angles were recorded with a Gloss Meter Poly-gloss GL0030 TQC device (TQC BV, Neuss, Germany) (Fig. 1D) in 100 mm × 100 mm × 17 mm samples according to the ISO 2813 (1994) standard. Ten replicates were used for each test.

Determination of color measurement

Red color (a^*) tone, yellow color (b^*) tone, lightness (L^*), hue ($H°$), chroma (C), and total color (ΔE^*) of 10 wood samples were determined using an X Rite Ci62 series portable instrument (X-Rite Europe GmbH, Regensdorf, Switzerland) with a wavelength resolution of 10 nm and measurement geometry D/8°) (Fig. 1E) with a D65 standard illuminant as per ASTM D2244-3 (2007). The CIELAB system, characterized by the three axes L^*, a^*, and b^*, was used. The L^* axis represents lightness, varying from 100 (white) to zero (black); a^* is the red (+) to green (–) tone; and b^* is the yellow (+) to blue (–) tone (Esteves *et al*. 2019). The corresponding changes ΔL^*, Δa^*, and Δb^* after weathering were determined using Eqs. 3 to 5:

$$\Delta L^* = L^*_{\text{weathered}} - L^*_{\text{un-weathered}} \quad (3)$$

$$\Delta b^* = b^*_{\text{weathered}} - b^*_{\text{un-weathered}} \quad (4)$$

$$\Delta a^* = a^*_{\text{weathered}} - a^*_{\text{un-weathered}} \quad (5)$$

The total color difference (ΔE^*) was calculated by Eq. 6:

$$\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2} \quad (6)$$

Statistical analysis

In this study, minimum values, maximal values, standard deviations, maximum values, homogeneity groups, analysis of variance, and multiple comparisons using data obtained before and after weathering were all determined using SPSS 17 software (Sun Microsystems, Inc., Santa Clara, CA, USA). One-way ANOVA followed by Duncan's multiple range test was used. The level of significance considered was 5%.

RESULTS AND DISCUSSIONS

The wood of *Citrus limon* has been shown to be a dense wood with an air density of approximately 834 kg/m^3 which is similar to orange wood that also belongs to the Rutaceae family with 827 kg/m^3 (Berti *et al*. 2018). The density of this kind of wood is comparable to that of Turkey oak (801 kg/m^3) (Bajraktari *et al*. 2018) or Rowan wood (801 kg/m^3) (Korkut *et al*. 2009), which are two dense woods from Turkey.

Janka hardness of *Citrus limon* wood was approximately 120.5 N/mm^2 for tangential, 115.9 N/mm^2 for radial, and 138.1 N/mm^2 for cross surfaces (Table 1). This means that its hardness is higher on the cross surface, followed by tangential and radial surfaces. A similar result was reported by Peng *et al*. (2016) for six different species: Chinese fir, red pine, Mongolian Scotch pine, Manchurian walnut, Asian white birch, and Mongolian oak. Holmberg (2000) studied the influence of grain angle on Brinell hardness of Scots pine (*Pinus sylvestris* L.) and concluded that this higher hardness on the cross surface may be because, when the load was applied parallel to the fiber direction, it was spread over several fibers but when it was applied perpendicularly, the amount of fibers carrying the load was lower. Nevertheless, a more plausible explanation would be that cohesive strength inside a fiber is higher than adhesive strength between many fibers.

The hardness of *Citrus limon* wood was higher than all of the woods presented in the work of Helińska-Raczkowska and Molinski (2003) with 13 different woods where the hardest wood from that study was hornbeam with 116.7 N/mm^2, 92.7 N/mm^2, and 86.0 N/mm^2 hardness in cross, tangential, and radial sections, respectively . Rowan wood is one of the hardest woods grown in Turkey with hardness of 259 N/mm^2, 116 N/mm^2, and 142 N/mm^2 in cross, radial, and tangential surfaces, respectively (Korkut *et al*. 2009). *Citrus limon* wood hardness is smaller for the cross-section but not that much smaller for tangential and radial surfaces. High hardness has already been reported for orange wood, which is also a member of the Rutaceae family (Berti *et al.* 2018). This shows that *Citrus limon* wood has a good potential to be used for flooring regarding its hardness.

The screw withdrawal resistance was also determined for the cross, radial, and tangential sections, and the results are presented in Table 1. The screw withdrawal resistance was higher for the radial section (53.98 N/mm^2) followed by the tangential (50.80 N/mm^2) and cross-sections (43.62 N/mm^2). Nail and screw withdrawal resistance is important when accessing the workability of wood. This is important for some kinds of flooring as for example stairs that usually require nails and screws.

Kiliç *et al*. (2007) studied the nail and screw withdrawal resistance of the most common woods used for flooring; the results were reported using a different unit (kgf) and using 5 mm x 50 mm screws with an entrance depth of 35 mm. Converting their results to N/mm^2, the screw withdrawal resistance values are, for oak (36.6 N/mm^2 (R), 35.4 N/mm^2 (T)) and 27.3 N/mm^2 (C)), walnut (32.9 N/mm^2 (R), 32.8 N/mm^2 (T) and 24.3 N/mm^2 (C)) and for cherry (28.0 N/mm^2 (R), 26.9 N/mm^2 (T) and 17.6 N/mm^2 (C)). Results show that the screw withdrawal resistance of *Citrus limon* is higher than all of these woods, showing that this wood has a good potential to be used for flooring that requires the using of screws.

The high screw withdrawal resistance of this wood was expected, since the parameter is dependent on density. It is known that there is a strong relationship between wood density and mechanical properties of wood. In previous studies, some researchers reported this relationship (Kollmann and Cote 1968; Malkoçoğlu 1994; Bektaş 1997; Bal and Bektaş 2018).

The color of *Citrus limon* wood was determined using the CIELAB system and presented in Table 1. According to the results, lightness was 83.4, showing that this wood is lighter than most commercial woods in Turkey. This wood has a lightness similar to poplar (83.5) or Uludag fir (84.3); however it is much lighter than chestnut (73.3), beech (69), black locust (61.3), red oak (60.5), Doussie (58.3), and Iroko (57.5) (Ayata *et al*. 2017a, 2018; Gurleyen *et al*. 2018). The *a** and *b** values show that this wood is mainly yellow.

The results of the variance analysis of the screw withdrawal resistance and Janka hardness strength in accordance to the surface are given in Table 2. According to the results, both Janka hardness and screw withdrawal resistance were considered to be significantly different between surfaces. Nevertheless the homogeneity groups presented in Table 3 show that the main differences were between the surfaces in the longitudinal direction (radial and tangential sections) compared to the transverse direction (cross-section). Similar results were obtained by Çavuş and Ayata (2018) related to screw withdrawal resistance of some wood species.

Table 1. Some of the Wood Properties of *Citrus limon* Wood

Property		N	Average	Minimum	Maximum
Physical Properties	Equilibrium moisture content (%)	10	8.94	8.60	9.60
	Air-dried density (kg/m^3)	10	834	822	842
Janka Hardness	Tangential (T) (N/mm^2)	10	120.45	112.90	125.80
	Radial (R) (N/mm^2)	10	115.94	101.50	123.30
	Cross (C) (N/mm^2)	10	138.05	128.70	150.40
Screw Withdrawal resistance	Tangential (T) (N/mm^2)	10	50.80	44.10	58.50
	Radial (R) (N/mm^2)	10	53.98	48.10	65.00
	Cross (C) (N/mm^2)	10	43.62	37.30	50.00
Color Parameters	Lightness (*L**) value	10	83.44	83.11	83.62
	Red color (*a**) tone	10	2.79	2.70	2.91
	Yellow color (*b**) tone	10	22.70	22.42	23.14
	Chroma (C)	10	25.69	25.52	25.84
	Hue (H^o)	10	82.04	81.72	82.11
Glossiness Values	Perpendicular (⊥) at 20°	10	1.22	1.20	1.30
	Perpendicular (⊥) at 60°	10	3.24	3.00	3.70
	Perpendicular (⊥) at 85°	10	3.62	3.50	3.70
	Parallel (//) at 20°	10	1.20	1.20	1.20
	Parallel (//) at 60°	10	4.50	4.40	4.50
	Parallel (//) at 85°	10	4.74	4.20	5.20
N: Number of measurements					

Table 2. Variance Analysis Results of Janka Hardness and Screw Withdrawal resistance Values for *Citrus limon* Wood Samples

Test	Source	Sum of Squares	df	Mean Square	F	Sig.
Janka Hardness	Surface	2729.841	2	1364.920	44.416	0.000*
	Error	829.714	27	30.730		
	Total	470910.600	30			
Screw Withdrawal resistance	Surface	563.315	2	281.657	12.753	0.000*
	Error	596.312	27	22.086		
	Total	74568.160	30			
*: Significant according to α ≤ 0.05; df: is degrees of freedom						

Table 3. Statistical Data for Janka Hardness and Screw Withdrawal resistance of *Citrus limon* Wood

Test Name	Surface	N	Mean (N/mm^2)	Homogeneity Group	Standard Deviation	Minimum	Maximum
Janka Hardness	Tangential	10	120.45	B	3.98	112.90	125.80
	Radial	10	115.94	B	6.52	101.50	123.30
	Cross	10	138.05	A*	5.82	128.70	150.40
Screw Withdrawal resistance	Tangential	10	50.80	A	4.79	44.10	58.50
	Radial	10	53.98	A*	5.36	48.10	65.00
	Cross	10	43.62	B	3.81	37.30	50.00
N: Measurements of number, *: Highest value							

The results of the variance analysis of color and perpendicular glossiness at 60° of un-weathered and weathered lemon wood are shown in Table 4. The results of variance analysis on lightness (*L**), red color tone (*a**), yellow color tone (*b**), and perpendicular glossiness at 20° and 60° angles were found significant according to α ≤ 0.05. That means the weathering period had a significant influence both on color and glossiness of the samples. The reason for the glossiness measured at 85° angle not being considered significant might have been due to more irregular results that generally occur at this angle, which may be due to surface roughness, as stated before (Ayata *et al*. 2017b).

Table 4. Results of the Variance Analysis of Color and Glossiness Before and After Weathering Applications

Test	Source	Sum of Squares	df	Mean Square	F	Sig.
Lightness (L^*)	Weathering Period	794.736	3	264.912	700.801	0.000*
	Error	13.608	36	0.378		
	Total	231052.551	40			
Red Color Tone (a^*)	Weathering Period	382.202	3	127.401	1097.147	0.000*
	Error	4.180	36	0.116		
	Total	2780.520	40			
Yellow Color Tone (b^*)	Weathering Period	955.301	3	318.434	420.595	0.000*
	Error	27.256	36	0.757		
	Total	34496.235	40			
Perpendicular Glossiness at 20°	Weathering Period	0.722	3	0.241	80.167	0.000*
	Error	0.048	16	0.003		
	Total	16.790	20			
Perpendicular Glossiness at 60°	Weathering Period	13.546	3	4.515	14.672	0.000*
	Error	4.924	16	0.308		
	Total	216.920	20			
Perpendicular Glossiness at 85°	Weathering Period	29.358	3	9.786	3.021	0.060**
	Error	51.832	16	3.240		
	Total	665.470	20			
*: Significant according to $\alpha \leq 0.05$, **: Insignificant according to $\alpha > 0.05$						

Table 5 shows the statistical data for perpendicular glossiness and color parameters before and after weathering. Lightness decreased with the increase of the weathering period, and exhibited a maximum 13.8% decrease, which means that the surface became darker. Similar results were presented before for artificial weathering of angelim pedra (*Hymenolobium* sp.), piquia (*Caryocar* sp.), Afzelia (*Afzelia* sp.), Iroko (*Milicia excelsa*), and Opepe (*Nauclea diderrichii*), although only for the first 30 to 50 cycles after which L^* increased again (Jankowska 2013, 2015). Both a^* and b^* increased with weathering, which meant that wood surface became redder and more yellow. A similar increase in both a^* and b^* was presented before for heat treated Scots pine aged for 500 h by Kucuktuvek *et al*. (2017). Glossiness generally decreased with weathering even though the biggest changes happened in the first 144 h of weathering, after which glossiness stayed approximately the same.

The results for total color difference are given in Table 6. As expected, total color difference increased with weathering. The ΔE^* reached its highest value in the first 144 h of weathering. Table 6 indicates that similar darkness was obtained at 144 and 288 h of accelerated weathering in lemon wood, then slightly increased after 288 h. In addition, total color change was remarkably increased at the final stage (432 h) of weathering.

Table 5. Statistical Data for Color Parameters and Perpendicular Glossiness Values Before and After Weathering Applications

Test	Weathering Period	N	Mean	HG	SS	Minimum	Maximum
Lightness (*L**)	Un-weathered	10	83.44	A*	0.18	83.11	83.62
	144 h	10	74.31	B	0.75	73.01	74.82
	288 h	10	73.79	B	0.88	72.79	75.26
	432 h	10	71.93	C**	0.38	71.48	72.38
Red Color Tone (*a**)	Un-weathered	10	2.79	D**	0.08	2.70	2.91
	144 h	10	8.07	C	0.60	7.17	8.52
	288 h	10	8.82	B	0.27	8.51	9.13
	432 h	10	11.27	A*	0.15	11.04	11.42
Yellow Color Tone (*b**)	Un-weathered	10	22.70	D**	0.25	22.42	23.14
	144 h	10	27.94	C	0.98	27.31	29.71
	288 h	10	28.75	B	1.20	27.03	30.09
	432 h	10	36.39	A*	0.76	35.13	37.36
Perpendicular Glossiness at 20°	Un-weathered	5	1.22	A*	0.04	1.20	1.30
	144 h	5	0.82	B	0.08	0.70	0.90
	288 h	5	0.74	C**	0.05	0.70	0.80
	432 h	5	0.80	BC	0.00	0.80	0.80
Perpendicular Glossiness at 60°	Un-weathered	5	4.50	A*	0.16	4.30	4.70
	144 h	5	3.04	B	0.84	2.00	3.90
	288 h	5	2.76	B	0.70	2.00	3.60
	432 h	5	2.30	B**	0.12	2.20	2.50
Perpendicular Glossiness at 85°	Un-weathered	5	3.62	B**	0.11	3.50	3.70
	144 h	5	6.50	A	2.61	3.10	9.30
	288 h	5	4.96	AB	2.18	1.60	6.80
	432 h	5	6.54	A*	1.16	5.70	8.50

N: Measurements of number, HG: Homogeneity group, SS: Standard Deviation, *: Highest value, and **: Lowest value

Table 6. Changes in Color Parameters After Accelerated Weathering for Lemon Wood

Weathering Period	Δ*L**	Δ*a**	Δ*b**	Δ*E**
144 h	-9.13	5.28	5.24	11.78
288 h	-9.65	6.03	6.05	12.89
432 h	-11.51	8.48	13.69	19.79

CONCLUSIONS

1. *Citrus limon* wood has been shown to be a dense wood with air density of 834 kg/m^3. The Janka hardness for *Citrus limon* wood was determined as 138.0 N/mm^2, 120.4 N/mm^2, and 115.9 N/mm^2 for cross, tangential, and radial sections, respectively, which along with density might allow this kind of wood to be used for flooring. Screw withdrawal resistance was good and higher in the radial surface (54.0 N/mm^2), followed by tangential and cross-sections. Janka hardness and screw withdrawal resistance were significantly different between surfaces, although the main differences were between the surfaces in the longitudinal direction and transverse direction.
2. Wood is lighter than most common woods with *L** of 83.4 and it is mainly yellow. Weathering darkened the wood and increased both *a** and *b** values. Glossiness

decreased in the first hours of the weathering period, and then stayed approximately the same afterwards. Total color change especially increased after 288 h of weathering.

3. The wood properties determined show that *Citrus limon* wood as good characteristics to be used for flooring applications.
4. It is thought that the knowledge of these properties might be useful when exploring new uses for this kind of wood. Nevertheless other properties have to be determined in order to access if this species can have other important applications.

REFERENCES CITED

ASTM D2244-3 (2007). "Standard practice for calculation or color tolerances and color differences from instrumentally measured color coordinates," ASTM International, West Conshohocken, PA, USA.

ASTM G154-06 (2006). "Standard practice for operating fluorescent light apparatus for UV exposure of nonmetallic materials," ASTM International, West Conshohocken, PA, USA.

Ayata, Ü., Gurleyen, L., and Esteves, B. (2017a). "Effect of heat treatment on the surface of selected exotic wood species," *Drewno* 60(199), 105-116. DOI: 10.12841/wood.1644-3985.198.08

Ayata, Ü., Gurleyen, L., Esteves, B., Gurleyen, T., and Cakıcıer, N. (2017b). "Effect of heat treatment (ThermoWood) on some surface properties of parquet beech (*Fagus orientalis* Lipsky.) with different layers of UV system applied," *BioResources* 12(2), 3876-3889. DOI: 10.15376/biores.12.2.3876-3889

Ayata, Ü., Sahin, S., Esteves, B., and Gurleyen, L. (2018). "Effect of thermal aging on colour and glossiness of UV system varnish-applied laminated parquet layers," *BioResources* 13(1), 861-868. DOI: 10.15376/biores.13.1.861-868

Bajraktari, A., Nunes, L., Knapic, S., Pimenta, R., Pinto, T., Duarte, S., Miranda, I., and Pereira, H. (2018). "Chemical characterization, hardness and termite resistance of *Quercus cerris* heartwood from Kosovo," *Maderas. Ciencia y Tecnología* 20(3), 305-314. DOI: 10.4067/S0718-221X2018005003101

Bal, B. C., and Bektaş, İ. (2018). "A research on the determination of the relationship between density and some mechanical properties of wood," *Furniture and Wooden Material Research Journal* 1(2), 51-61. DOI: 10.33725/mamad.467353

Bektaş, İ. (1997). "Technological properties of calabrian pine (*Pinus brutia* Ten.) and depending upon growing regions," Istanbul University, Institute of Graduate Studies in Science and Engineering, Department of Forest Industrial Engineering, Ph.D. Thesis, Istanbul, Turkey.

Berti, S., Burato, P., Dionisi-Vici, P., and Allegretti, O. (2018). "Orange wood for parquet and engineered flooring use," *BioResources* 13(1), 586-596. DOI: 10.15376/biores.13.1.586-596

Çavuş, V., and Ayata, Ü. (2018). "An investigation on screw withdrawal resistance on woods of magnolia tree, maple and chinaberry tree," *Furniture and Wooden Material Research Journal* 1(2), 94-102. DOI: 10.33725/mamad.496615

Esteves, B., Ayata, Ü., and Gurleyen, L. (2019). "Effect of heat treatment on the colour and glossiness of black locust, wild pear, linden, alder and willow wood," *Drewno* 62(203), 39-52. DOI: 10.12841/wood.1644-3985.267.10

Fang, C. H., Blanchet, P., Cloutier, A., and Barbuta, C. (2012). "Engineered wood flooring with a densified surface layer for heavy-duty use," *BioResources* 7(4), 5843-5854. DOI: 10.15376/biores.7.4.5843-5854

Gurleyen, L., Esteves, B., Ayata, Ü., Gurleyen, T., and Çınar, H. (2018). "The effects of heat treatment on colour and glossiness of some commercial woods in Turkey," *Drewno* 61(201), 81-90. DOI: 10.12841/wood.1644-3985.227.03

Helińska-Raczkowska, L., and Moliński, W. (2003). "The effect of the Janka ball indentation depth on the hardness number determined for selected wood species," *Folia Forestalia Polonica. Series B-Drzewnictwo* 34, 27-36.

Holmberg, H. (2000). "Influence of grain angle on Brinell hardness of Scots pine (*Pinus sylvestris* L.)," *Holz als Roh-und Werkstoff* 58(1-2), 91-95. DOI: 10.1007/s001070050392

ISO 2813 (1994). "Paints and varnishes - determination of specular gloss of non-metallic paint films at 20 degrees, 60 degrees and 85 degrees," International Organization for Standardization, Geneva, Switzerland.

Jankowska, A. (2013). "The study of changes in color of wood angelim pedra (*Hymenolobium* sp.) and piquia (*Caryocar* sp.) during artificial weathering," *Annals of Warsaw University of Life Sciences - SGGW, Forestry and Wood Technology* 82, 339-343.

Jankowska, A. (2015). "The study of influence artificial weathering on color changes of selected wood species from Africa," *Annals of Warsaw University of Life Sciences - SGGW, Forestry and Wood Technology* 92, 131-136.

Kiliç, M., Burdurlu, E., İlker, U., Berker, U. Ö., and Oduncu, P. (2007). "Comparative analysis of the nail and screw withdrawal resistances of fir (*Abies* Mill.), cherry (*Prunus Avium* L.), walnut (*Juglans Regia* L.) and oak (*Quercus* L.) wood," *Duzce University Journal of Forestry* 2(2), 61-75.

Kollmann, F. F. P., and Cote, W. A. (1968). *Principles of Wood Science and Technology*, Springer Verlag, Berlin, Germany.

Korkut, S., Guller, B., Aytin, A., and Kök, M. S. (2009). "Turkey's native wood species: Physical and mechanical characterization and surface roughness of Rowan (*Sorbus aucuparia* L.)," *Wood Research* 54(2), 19-30.

Kucuktuvek, M., Baysal, E., Turkoglu, T., Peker, H., Gunduz, A., and Toker, H. (2017). "Surface characteristics of Scots pine wood heated at high temperatures after weathering," *Wood Research* 62(6), 905-918.

Malkoçoğlu, A. (1994). "Technological properties of oriental beech (*Fagus orientalis* Lipsky.) wood," Karadeniz Technical University, The Graduate School of Natural and Applied Sciences, Forest Industrial Engineering Graduate Program, Ph.D. Thesis, Trabzon, Turkey.

Meier, E. W. (2015). "Identifying and using hundreds of woods worldwide," Wood Database.

Peng, H., Jiang, J., Zhan, T., and Lu, J. (2016). "Influence of density and equilibrium moisture content on the hardness anisotropy of wood," *Forest Products Journal* 66(7-8), 443-452. DOI: 10.13073/FPJ-D-15-00072

TS 2471 (1976). "Wood, determination of moisture content for physical and mechanical tests," Turkish Standards Institute, Ankara, Turkey.

TS 2472 (1976). "Wood- Determination of density for physical and mechanical tests," Turkish Standards Institute, Ankara, Turkey.

TS 2479 (1976). "Wood – Determination of static hardness," Turkish Standards Institute, Ankara, Turkey.

TS EN 13446 (2005). "Wood-based panels – Determination of withdrawal capacity of fasteners," Turkish Standards Institute, Ankara, Turkey.

Uzcategui, M. G. C., Seale, R. D., and França, F. J. N. (2020). "Physical and mechanical properties of clear wood from Red oak and White oak," *BioResources* 15(3), 4960-4971. DOI: 10.15376/biores.15.3.4960-4971

Wahl, A. (2000). *A Market Assessment of Wood Use in Japanese Residential Flooring of Windows*, Ph.D. Dissertation, University of British Columbia.

Yildirim, B., Yeşiloğlu, T., Uysal Kamiloğlu, M., Incesu, M., Tuzcu, Ö., and Çimen, B. (2010). "Fruit yield and quality of Santa Teresa lemon on seven rootstocks in Adana (Turkey)," *African Journal of Agricultural Research* 5(10), 1077-1081. DOI: 10.5897/AJAR09.229

Yilmaz, E., and Güneşer, B. A. (2017). "Cold pressed *versus* solvent extracted lemon (*Citrus limon* L.) seed oils: Yield and properties," *Journal of Food Science and Technology* 54(7), 1891-1900. DOI: 10.1007/s13197-017-2622-8.

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