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Determination of Some Physical and Mechanical Properties of Apricot Wood (*Prunus armeniaca* L.)

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Abstract

In this study, it was aimed to determine some physical and mechanical properties of apricot wood (*Prunus armeniaca* L.) which was grown in Malatya province. For this purpose, air-dry density, modulus of rupture (MOR), modulus of elasticity (MOE), impact bending strength (IB) and screw holding capacity (SHC) (radial, tangential and axial direction) of apricot wood (*Prunus armeniaca* L.) were determined. According to the tests results; air-dry density was found as 0.788 g/cm^3, IB as 2.32 kj/m^2, MOR as 81.88 N/mm^2 and MOE as 6569 N/mm^2 and SCH (radial, tangential and axial direction) were determined as 47.34, 48.89 and 44.38 N/mm^2 respectively. The obtained data were compared with the important industrial wood species and it has been concluded that this wood species has important technological properties.

Keywords: Apricot Wood, physical properties, mechanical properties.

Kayısı Ağacı (*Prunus armeniaca* L.) Odununun Bazı Fiziksel ve Mekanik Özelliklerinin Belirlenmesi

Öz

Bu çalışmanın amacı, Malatya yöresinde yetişen Kayısı (*Prunus armeniaca* L.) ağaç türüne ait odunda bazı mekanik ve fiziksel özelliklerinin belirlenmesidir. Bu amaç ile kayısı odununda hava kurusu yoğunluk eğilme direnci, eğilmede elastikiyet modülü, dinamik eğilme (şok) direnci ile radyal teğet ve boyuna yönde vida tutma kapasitesi belirlenmiştir. Yapılan testlere ait sonuçlara göre; hava kurusu yoğunluk değeri 0.788 g/cm^3 dinamik eğilme (şok) direnci 2.32 kj/m^2, eğilme direnci 81.88 N/mm^2 ve eğilmede elastikiyet modülü 6569 N/mm^2 ve radyal, teğet ve boyuna yönde vida tutma kapasitesi sırasıyla 47.34, 48.89 ve 44.38 N/mm^2 olarak tespit edilmiştir. Elde edilen veriler önemli endüstriyel odun türleri ile karşılaştırılmış ve bu ağaç türünün teknolojik yönden önemli özelliklere sahip olduğu sonucuna ulaşılmıştır.

Anahtar Kelimeler: Kayısı ağacı, fiziksel özellikler, mekanik özellikler.

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1. Introduction

Prunus armeniaca L. is known as apricot. It is a Rosaceae family member and belongs to the section Armeniaca (Lam.) (Zhebentyayeva et al., 2012). Usually, an apricot tree is from the species P. armeniaca. The apricot tree is closely related to four species (P. brigantina, P. mandshurica, P. mume, P. zhengheensis and P. sibirica), and they have similar fruits, and are also called apricots (Bortiri et al., 2001; URL.1, 2020). Apricot (*Prunus armeniaca* L.), which is now generally accepted as a fruit of Chinese origin with a growing history of more than 3000 years in China, has been widely grown throughout the world except for Antarctica (Jiang et al., 2019). World Apricot Production volume map is shown in figure 1. Turkey is shown with the green bubble).

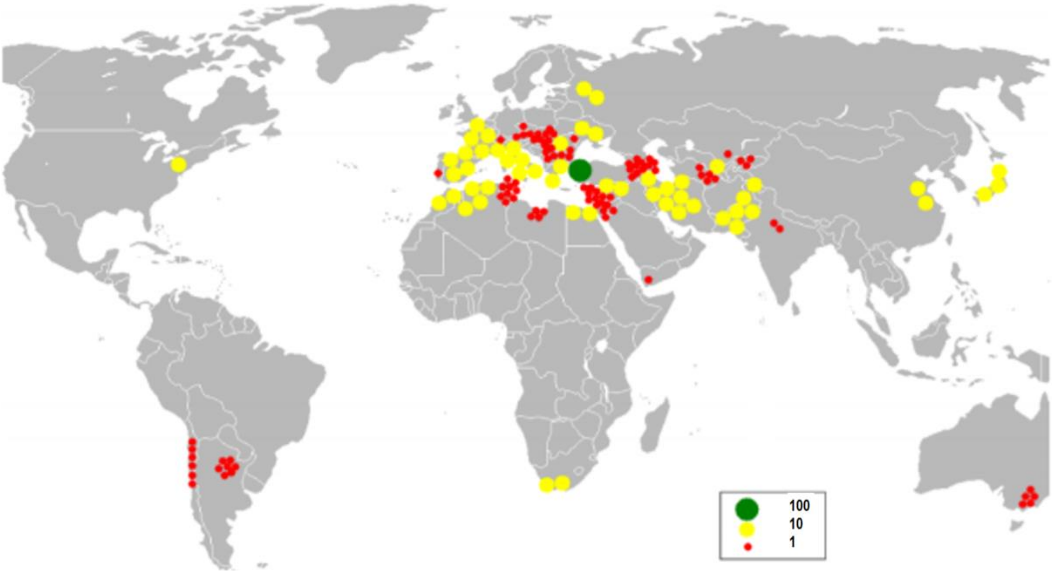

Figure 1: World Apricot Production volume Map (URL.1).

The global distribution of the apricot tree is shown in figure 1. This bubble map shows the global distribution of apricot output in 2005 as a percentage of the top producer (Turkey - 390,000 tons). World apricots production volume was 4.3 million tons in 2017. Turkey is the leader with 23% of the world total. Other major producers are Uzbekistan, Italy, Algeria, and Iran (FAO, 2020). World Apricot Planting Area (ha) is shown in Table 1. Apricot trees are planted in 568 thousand (ha) area in the world. World total apricot production areas are located in Turkey with 21.8%, in Uzbekistan with 9.9%, in Iran with 9.6% and in Algeria with 6.7% (FAO, 2020).

Table 1. World Apricot Planting Area (ha) (FAO, 2020)

Country	**2012**	**2013**	**2014**	**2015**	**2016**
Turkey	114.052	115.613	117.907	123.176	123.805
Uzbekistan	42.300	46.511	50.250	53.473	56.206
Iran	35.461	53.205	53.624	54.500	54.392
Algeria	47.376	46.893	38.590	38.857	38.239
Pakistan	27.536	28.578	26.950	25.746	26.461
Syria	13.801	13.780	13.783	13.279	14.656
Italy	19.186	18.999	19.093	18.718	18.917
Spain	18.542	20.300	18.451	18.822	18.353
Japan	16.400	16.200	16.200	15.900	15.600
Others	181.379	181.826	182.059	182.786	182.160
Total	532.322	558.924	554.657	563.742	568.014

Apricot tree can live between 20 and 40 years depending on variety and growth conditions. The apricot tree usually has, 8–12 m tall, with a trunk up to 40 cm in diameter. Farmers prefer cutting down the trees, which are especially over 40 years old with the decrease of yield and planting young ones and the old ones are used as firewood (Tutuş et al., 2016). Apricot (*Prunus armeniaca* L.) has homogeneous wood with scattered vessels and heartwood. Vascular cavities are often isolated, with small-diameter, round and cross-section, and to some extent tight. The great wooden beams and rings can be barely seen. Wooden rays are awider if the ring is smaller than the rays (Olvera et al., 2008; Tajik et al., 2015). The chemical composition of apricot wood (*Prunus armeniaca* L.) is as follows: holocellulose (79.50%), alphacellulose (42.33%), and lignin (16.43%) (Gencer et al., 2018) ash 0.48%, solubility in toluene-acetone-ethanol 5.88%, 1% NaOH resolution 27.40%, hot water solubility 7.74% and cold water solubility 4.20% (Tutuş et al., 2016). Morphological properties of apricot wood are as follows: (in heartwood) fiber length 0.717 mm, fiber width 13.75 µm, lumen Ø6.05 µm wall thickness 3.85 µm Specific Weight 0.54 g/cm^3, (in sapwood) fiber length 0.694 mm fiber width 12.08 µm lumen Ø 5.69 µm wall thickness 3.19 µm and specific weight 0.63 g/cm^3 (Gencer et al., 2018). Color properties of the apricot wood are also as follows: lightness values of (L*) 51.57, the green-red (a*) 9.54, yellow-blue color coordinates (b*) 22.04, Chroma or 'saturation' properties 66.59, angle of the line starting from the point to the zero origin 21.35°, Whiteness 17.06 and Yellowness 71.05 (Sahin and Onay, 2020). Some other properties of apricot wood are as follows: Density 0.75 (g/cm^3) Hardness (Janka) 6.9 (kN) Crushing strength 46.0 (MPa) (Meier 2015). Janka hardness of Apricot wood for tangential, radial and axial sections; 65.09 74.07 and 80.46 N/mm^2, respectively (Ayata and Bal, 2019).

Apricot wood has straight and clear grain. Thanks to these properties, apricot is easy to work with hand or machine tools. The apricot wood can be used for making furniture, wood carvings, wood turnings musical instrument and hand-made souvenirs. Some studies conducted on apricot wood have revealed that it can be used in particleboard, pulp and paper manufacturing (Enayatı et al., 2009; Tutuş et al., 2016). Apricot wood is similar to the hardwood species that have industrial value, so it is a convenient raw material for pulp production (Gencer et al., 2018).

In this study, some mechanical and physical properties of apricot (*Prunus armeniaca* L.) wood, which were grown in Malatya province, were determined. There is a few and little data on the physical and mechanical wood properties of apricot (*Prunus armeniaca* L.) wood in the literature. Having knowledge of anatomical, chemical, physical, mechanical, and other technological properties of the wood is the most important factor before deciding to use it in the right place effectively. It is thought that; the determined physical and mechanical properties will provide important information about the usage areas of this wood.

2. Material ve Method

2.1. Material

In the study, apricot (*Prunus armeniaca* L.) wood specimens, which were grown in Malatya province, were used. Apricot wood were purchased from lumber seller in Malatya province. The principles stated in the TS 2470 (1976) standard were taken into consideration in the preparation of test specimens. Test specimens were prepared by cutting radially from parts of sapwood with the straight grain and without knot, crack, wood defect, color difference, reaction wood, fungal and insect damage. Test specimens were conditioned at room condition with a relative humidity of %65 ± 5 and temperature of 20 ± 2 °C during 6 months until they became air dry. After the test; in order to determine the moisture content samples were taken from the test samples which were close to the place where the breakage occurred. The color of the supplied apricot wood was light brown with the darker brown grain.

2.2. Method

Air-dry density (D_{12}) of the test specimens were determined based on the TS 2472 (1976) standard. Dimensions of test specimens for the air-dry density were 20×20×20 mm (radial, tangential and axial sections). The dimensions and weight of test specimens were determined for air-dry density with 0.01mm sensitivity electronic caliper and electronic balance and the density were calculated according to the following equations (1)

$$D_{12} = \frac{M_{12}}{V_{12}} = (g/cm^3) \qquad (1)$$

Where;
D_{12}= Air-dry density (g/cm^3),
M_{12}= Air-dry weight (g),
V_{12}= Air-dry weight (cm^3).

In order to determine the modulus of rupture (MOR) of the 15 test specimens with the dimensions of 20x20x360 mm (radial, tangential and axial sections) were prepared in accordance with TS 2474 (1976). The dimensions of the test specimens were determined by measuring at a sensitivity of 0.01 mm. The distance between the centers of the cylindrical heads where the test specimen was placed was set to 13 times the thickness of the test specimen (13 X 20 mm = 260 mm). The load was uniformly loaded onto the surface of the test specimen at a constant rate and the test speed was adjusted to break 1.5 ± 0.5 min. after the test specimen started loading. The force at the moment of breaking (Pmax) was read and the MOR was calculated according to the following equation (2). The loads were applied in the tangential direction. The schematic view of the MOR test and the image of the test specimens are shown in figure 2.

$$\sigma_E = \frac{3.P_{max}.L}{2.b.h^2}\left(N/mm^2\right) \qquad (2)$$

Where;
Pmax= maximum load applied at break (N),
L = distance between the centers of the cylindrical spans (mm),
b = width of the test specimen (mm),
h = thickness of the test specimen (mm).

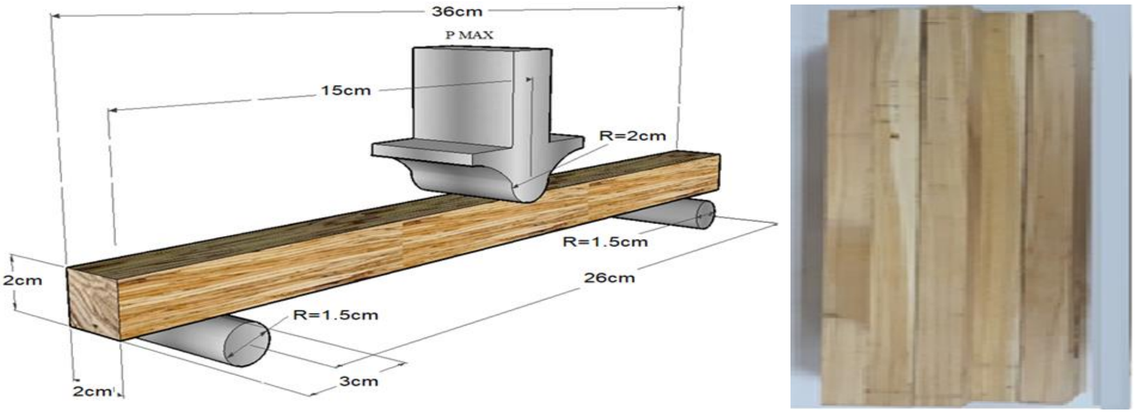

Figure 2. The schematic view of the MOR test and the test specimens

Modulus of elasticity (MOE) was determined with the same test specimens of MOR. MOE was calculated according to the following equation (3). MOE test specimens were determined according to Turkish standart TS 2478 (2005). The loads were applied in the tangential direction.

$$E = \frac{\Delta.F.L^3}{4.b.\ h^3 \Delta f}\left(N/mm^2\right) \qquad (3)$$

Where;
F = force equals to the difference between the arithmetic means of the upper and lower limits of the load in the elastic deformation zone (N),
L = the distance between the spans points (mm),
f = deflection in the net bending area, the difference between the arithmetic means of the deflection results measured at the lower and upper limits of the load (mm),
b = width of the test specimen (mm),
h = thickness of the test specimen (mm).

The IB was determined according to TS 2477 (1976). IB was determined with 15 test specimens with the dimension 20x20x300 mm (radial, tangential and axial sections). IB was determined at span to depth ratio which was 12 (12x20=240 mm span length). The loads were applied in the tangential direction. Schematic view of the IB test and pendulum impact test machine are shown figure 3. IB was calculated according to the following equation (4).

$$AW = \frac{Q}{bXh}(kj / m^2) \qquad (4)$$

Where;
A_W = impact bending strength (kj/m^2)
Q = absorbing energy (kj).
b = width of the test specimen (cm),
h = thickness of the test specimen (cm).

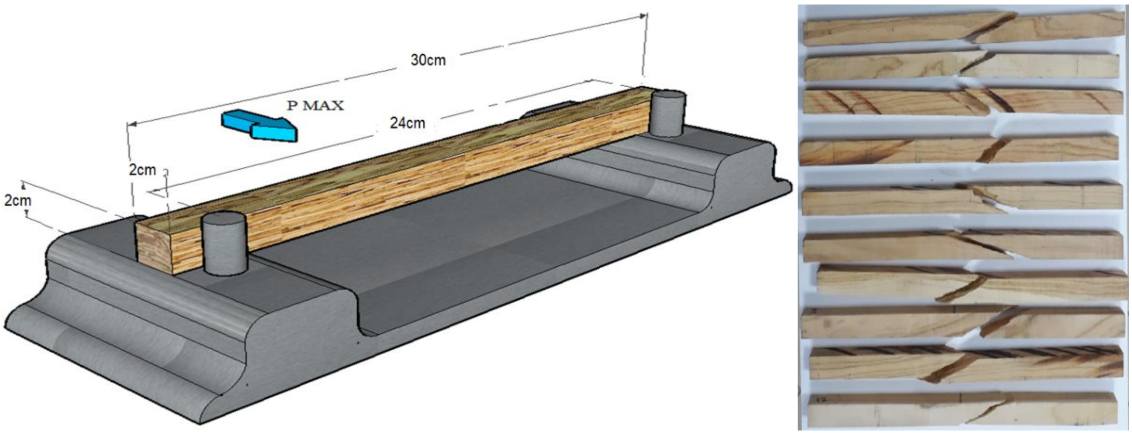

Figure 3. Schematic view of the IB and specimens views after test.

Nails, screws and bolts are most commonly used in woodworking industry (Taj et al., 2009). SHC of test specimens were determined on the three surfaces (tangential, radial and axial sections) according to the TS EN 13446 (2005) standard. The schematic view of SHC of test and the test specimens are shown in figure 4. SHC was determined with 15 test specimens with the dimension 50x50x50mm (radial, tangential and axial sections). In the study, screws with 4 mm diameter and 50 mm length were used. Firstly, the middle of the test specimens were drilled with the diameter 2.5 drill bit for pilot hole. The screws were screwed 20 mm into the test specimens through the pilot hole. The speed of the testing machine was set at 4 mm/min. SHC was calculated according to the following equation (5).

$$f = \frac{F_{max}}{dXl_p}\ N/mm^2 \qquad (5)$$

Where;
f= Screw holding capacity (N/mm^2),
Fmax =maximum force at the end of test (N),
d =diameter of the screw,
lp = screw length entering samples.

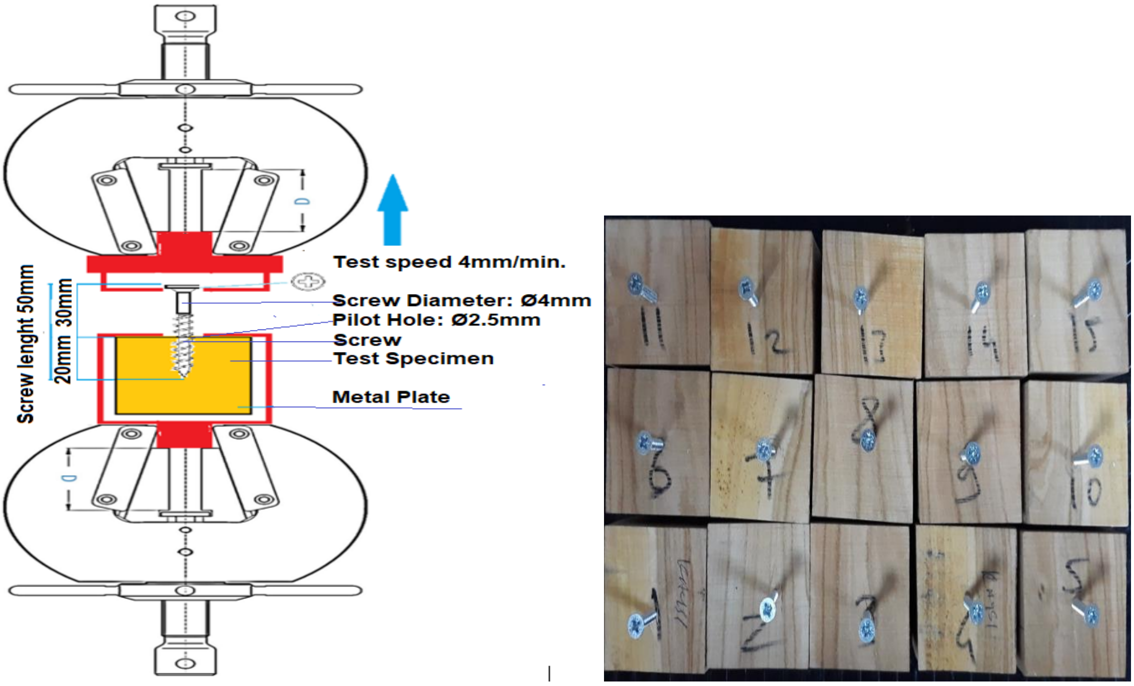

Figure 4. The schematic view of SHC of test and the test specimens.

3. Results and Discussions

There is little data on the physical and mechanical properties of the apricot (*Prunus armeniaca* L.) wood in the literature. The air-dry density, MOR, MOE, IB and SHC (radial, tangential and axial direction) of apricot (*Prunus armeniaca* L.) wood specimens are shown in Table 2. The average air-dry density of the apricot (*Prunus armeniaca* L.) is 0.788 g/cm^3. In another study, air-dry density of apricot wood was found to be 0.815 g/cm^3 (Ayata and Bal, 2019). In some studies with different types of wood, air-dry density values were determined as follows: Plane 0,625 g/cm^3, Eastern Beech 0.602 g/cm^3, Yellow pine 0.515 g/cm^3, (Bektaş et al 2005); Poplar 0.375 g/cm^3 (Tunçtaner, 2004); Eucalyptus 0.604, walnut 0,78 g/cm^3, Fir 0,49 g/cm^3, Black Pine 0,43 g/cm^3, redpine 0,46 g/cm^3, and Oak 0.776 g/cm^3 (Bal and Bektaş, 2012; Bektaş et al., 2016; Bal and Bektaş, 2018). The air-dry density of the apricot wood is higher than some of industrial wood species. Wood density is an important wood property for both solid wood and fiber products (Okoh, 2014).

The average MOR of apricot (*Prunus armeniaca* L.) were determined 81.88 N/mm^2. In some studies with different types of wood, MOR values were determined as follows: Birch 135.92 N/mm^2 (Bal et al, 2018a), Black cypress 113.27 N/mm^2 (Bal et al, 2018b), Wild cherry 95.39 N/mm^2 (Aytin, 2013), European Larch 82.34 N/mm^2 (Akpınar, 2012), Schotch pine 82.46 N/mm^2, Beech 105.7 N/mm^2, Poplar 66.84 N/mm^2 (Doruk and Perçin, 2010) redpine 54.33 N/mm^2, Juniper 51.00 N/mm^2 (As et al., 2001). The MOR values of the apricot wood are higher than poplar, Calabrian pine and Juniper wood species but it is lower than Birch, Beech, Black cypress Wild cherry. The modulus of rupture is an accepted criterion of wood strength (Kretschmann and Bendtsen, 1992).

Table 2. physical and mechanical properties of apricot (*Prunus armeniaca* L.) wood.

Tests	Results				
	N	$\bar{x}$	SD	Min.	Max.
Air-Dry Density (g/cm^3)	15	0.788	18.11	0.760	0.811
Modulus Of Rupture* (N/mm^2)	15	81.88	15.35	57.20	112.80
Modulus Of Elasticity* (N/mm^2)	15	6569	1078	5233	8651
Impact Bending Strength (kj/m^2)	15	2.32	0.066	1.50	3.67
Screw Holding Capacity In Radial N/mm^2)	15	47.34	3.71	42.25	54.01
Screw Holding Capacity In Tangential (N/mm^2)	15	48.89	2.92	45.44	54.60
Screw Holding Capacity In Axial (N/mm^2)	15	44.38	3.39	39.05	51.04

* MORand MOE strenght values were found in kg/cm^2 and then converted to N/mm^2.

The average MOE of apricot (*Prunus armeniaca* L.) is found as 6569 N/mm^2. In some studies with different types of wood, MOE values were determined as follows: European Larch (*Larix decidua* Mill.) 20045.75 N/mm^2 (Akpınar, 2012), Birch (*Betula pendula*) 16887 N/mm^2 (Bal et al., 2018a), Black cypress (*Cupressus sempervirens*) 13203 N/mm^2 (Bal et al., 2018b), Wild cherry (*Cerasus avium* (L.) Monench) 12793 N/mm^2 (Aytin, 2013), Poplar (*Populus* subsp.) 4214 N/mm^2 (Orhan, 2017). According to this comparison, the MOE values of apricot wood are lower than European Larch, Beech and Birch wood species but higher than the Poplar wood.

Wood material can be exposed to shock effects at some usage areas such as tool handle, packaging, upholstery, sports material. IB of apricot wood was investigated to determine the degree of resistance such uploads. The average IB of apricot (*Prunus armeniaca* L.) was determined as 2.32(kj/m^2). In some studies with different types of wood IB values were determined as follows: Beech 7.20, eucalyptus 7.64 (Bal and Bektaş, 2012), Black Cypress (*Cupressus sempervirens*) 2.80 (kj/m^2) (Bal et al., 2018b), birch (*Betula pendula*) 6.80 (kj/m^2) (Bal et al., 2018a). Test result were compared with data from previous studies; The IB values of apricot wood were found to be lower than that of these wood species (Birch, beech,and Black Cypress) values.

The average SHC (radial, tangential and axial direction) values of apricot (*Prunus armeniaca* L.) are 47.34, 48.89 and 44.38 N/mm^2 respectively. The average SHC of tangential direction is higher than the radial and axial direction. The lowest SHC were determined in axial direction. Due to the anisotropic nature of the wood, its properties are highly dependent on the direction. It is stated that wood sections are effective on the screw holding capacity (Kılıç et al., 2007; Çağatay et al., 2012; Gašparík et al., 2015; Çavuş and Ayata, 2018). Occasionaly screw holding capacity depends on wood density (Bal et al., 2013; Bal et al.,, 2016). In another study of apricot wood, results which were similar to the results of another study about nail holding capacity of the apricot wood (Ayata and Bal, 2019). The Nail holding capacity of the apricot wood were in tangential, radial and axial sections were determined as 16.05, 21.07 and 21.83 N/mm^2 respectively. The nail holding capacity values of apricot wood have been found to be lower (Ayata and Bal, 2019) than the SHC values in all direction of this study. It can be recommended that screws can be used instead of nails in making furniture and similar applications with this type of wood in all direction.

4. Conclusion

In this study, some physical and mechanical properties of apricot wood, which were grown in Malatya province, were determined. According to the obtained results from the test specimens as follows;

1. Average air-dry density of apricot wood were determined as 0.788 g/cm^3. Average MOR, MOE, IB values are 81.88 N/mm^2, 6569 N/mm^2 and 2.32 (kj/m^2) respectively.
2. The average SHC (radial, tangential and axial direction) of apricot (Prunus armeniaca L.) wood specimens are 47.34, 48.89 and 44.38 N/mm^2 respectively.
3. It is thought that; the test results can provide important information about the usage areas of this wood species. The results obtained in this study have provided information on the physical and mechanical properties of apricot wood species. The data may be used for furniture construction or other applications.
4. More studies of apricot wood may reveal different physical and mechanical properties which have not been determined in this study.

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