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EFFECT OF TREE DIAMETER CLASSES ON THE PROPERTIES OF PERSIAN OAK (*QUERCUS BRANTII* LINDL.) WOOD

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ABSTRACT

This study was conducted to investigate the properties of Persian oak (*Quercus brantii* Lindl.) wood, the most abundant tree species, harvested in the west and southwest regions of Iran. To the best our knowledge, there were no reported studies investigating the physical, chemical and biometrical features of Persian oak wood. For this purpose, 12 healthy trees in three diameter classes including 10-20, 20-30 and 30-40 cm were selected randomly and a disk was cut from each one at breast height. Results indicated that the highest basic densities are related to the diameter class 20-30cm (0.98 g·cm^{-3}) and the lowest one at diameter class 10-20 cm (0.88 g·cm^{-3}). The highest shrinkage was determined at oak wood samples from the diameter classes 10-20 cm (14.15%). Fiber length varied between 0.82 g·cm^{-3} (Dia. Class 10-20 cm, middle part) to 1.01 (Dia. Class 20-30 cm, bark). With increasing diameter, the cellulose content increased and the lignin content decreased while ash and extractive content was quite constant.

KEYWORDS: Persian oak wood, physical properties, chemical properties, biometrical properties.

INTRODUCTION

Wood as a raw material can be used in a wide variety of applications such as poles, housing, fences, decks, paper manufacture, fuel, children playgrounds etc. The growing demand for wood and wood products and also great pressure on the limited forest resources worldwide, hence a comprehensive plan is needed to supply the wood in the wood and paper industry to compensate the lack of wood materials. It is forecasted, that world will face with wood shortages in this century (Temperli et al. 2017). One useful way to utilize the forest resources are determined the quality characteristics of wood with regards to the growing place conditions and its appropriate use. One of the model locations are Zagros Forests cover about 5 million ha in Iran. These forests offer an excellent example, how the continental forests in Eurasia can look lie in the future, if the global warming will be increasing. The Zagros Mountains are divided into two parts: northern and Southern. The southern Zagros is included *Q. persica*. Persian oak (*Quercus brantii* Lindl.) from Fagacea family is the most abundant and important wood species in west and southwest provinces of Iran. That its biometrical, physical and chemical features is not studied so far. These tree species represents approximately 70 % of the tree species in Zagros forests. Most studies is related to wood species in northern Iran such as beech (*Fagus orientalis*), hornbeam (*Carpinus betulus*) and alder (*Alnus glutinosa*), ash (*Fraxinus excelsior*), as well as the rapid growing wood species like aspen (*Populus deltoide*), eucalyptus (*E. camaldulensis*) (Varshoie tabrizie et al. 2006, Hemassi et al. 2006, Efhami sisi and Saraeyan 2009, Dahmardeh 2001, Kieai and Samariha 2011). In this study, *Q. brantti* species has been evaluated and the most important qualitative properties including fiber dimensions (fiber diameter, lumen width, cell wall thickness) and physical features (dry and basic density, volumetric shrinkage and swelling) as well as chemical characteristics (extractives, lignin, cellulose, ash) with regard to radial position in tree were investigated. The variation of wood characteristics depends on several factors such as climate conditions, ecological interaction, and wood position in different parts of tree, between and within species (Koch 1985). There has been several studies performed on the other wood species other origin, but there has not been similar studies performed of Iranian origin. Doosthosseini and Parsapajooh (1996) reported that Beech fiber length increase from the pith to the bark while the fiber length decreases from the bottom to the top. Bakhshi et al. (2011) investigated the variation of *Quercus castaneaefolia* biometric properties regarding radial position and found that fiber length, fiber diameter, lumen width, cell wall thickness of springwood and summerwood along radial direction from the pith to bark increased. As the *Q. persica* and *Q. brantii* are one of the most important wood species in Middle East and predominantly in Iran, it is of great importance to elucidate the properties of these wood species in detail. Detail understanding of this material will enable better understanding of these materials and use for the applications with high added value.

MATERIAL AND METHODS

Materials

This study was conducted on twelve Persian oak (*Quercus brantii* Lindl.) trees in three diameter classes including 10-20, 20-30 and 30-40 cm were harvested from natural forests in Lordegan-Charmahal and Bakhtiari province in the southwest of Iran. Disks and logs from each sampled tree were cut at breast height. The annual rainfall and annual average temperature was 555 mm and 16.7°C, respectively. December and November are high-rain months and June and July are low-rain months. The temperature reaches its maximum level in June, July and August. The altitude of this site was 1580 m.

Determination of physical properties

Discs, 5 cm in thickness, were taken out from logs for determination of physical properties such as oven-dry density, basic density, volumetric shrinkage and volumetric swelling. Determination of wood density was carried out based on ISO-3131 standard. For determining the physical properties, testing samples with dimensions of 2 × 2 × 2 cm were obtained in accordance with the ASTM-D143 and used for measuring the oven-dry and basic density, longitudinal, radial, tangential and volume shrinkage. Testing samples were prepared from the pith to the bark. The physical properties of the samples were calculated using the following equations:

$$D_0 = M_0 / V_0$$
$$D_b = M_0 / V_s$$

$$\%\beta = \frac{D_s - D_{o.d}}{D_s} \quad (\%)$$

$$\%\alpha = \frac{D_s - D_{o.d}}{Do.d} \quad (\%)$$

where: D_0 is oven dry density (g·cm^{-3}),
D_b is basic density (g·cm^{-3}),
β- volumetric shrinkage (%), α is volumetric swelling (%),
D_s- volume in state of saturate (g·cm^{-3}),
D_0 - volume in state of oven-dry (g·cm^{-3}),
M_0 - weight in state of oven dry (g),
M_s - weight in state of saturate.

Determination of biometric properties:

From Franklin (1964) method was applied for separation of wood fiber in such a way that a wood samples with the dimension of saturated in a mixture (1:1) of acetic acid and oxygenized water in test tubes. The samples were put in an oven with 65±3°C for 48 hour. After maceration, the samples were washed (2-3 times) in distilled water and then the samples were saturated with distilled water, shaked and biometric properties were determined.

Determination of chemical properties

The chemical constitutes were performed according to the TAPPI Test Methods: Cellulose (T 257 cm-85): the lignin (T 222 om-98), ash (T 211 om-93), and solubility alcohol-acetone (T 204 cm-88). The cellulose content of oak wood was determined according to the nitric acid method (Rowell et al. 1997). All measurements were repeated three times, and the mean value was used.

RESULTS AND DISCUSSION

Density of the material is one of the first and elementary information. Dense material has better mechanical properties and are more resistant to wear. As can be seen from Fig. 1 (a, b and c), the density of the Persian oak is quite high. Basic density is ranging between 0.85 g·cm^{-3} and 1.01 g·cm^{-3}.

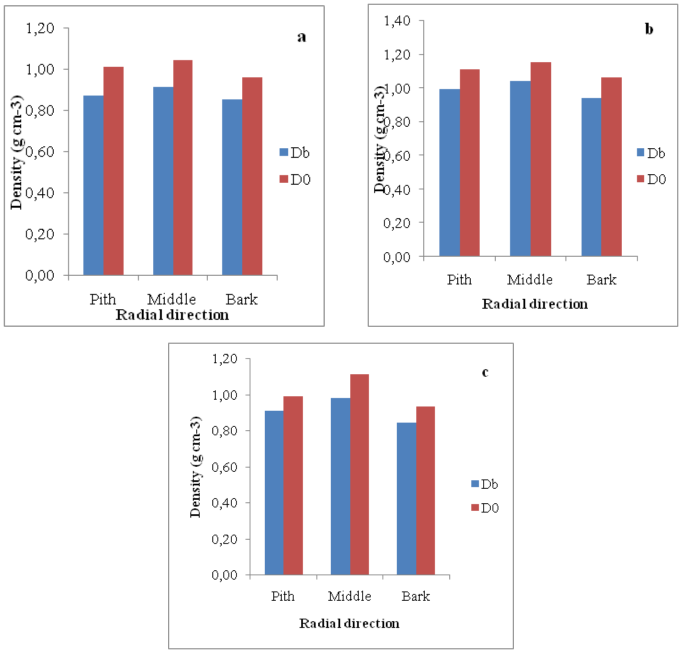

Fig. 1: Influence of three diameters on the basic and oven-dry density of oak wood.
a: Dia. Class 10-20, b:Dia. Class: 20-30, c: Dia. Class 30-40.

This makes considerable difference from the European oak, where the average density 0.69 g·cm^{-3} (Wagenführ 1996) was reported. The highest basic densities are reported for wood coming from diameter class 20-30 cm (0.98 g·cm^{-3}) and the lowest one at diameter class 10-20 cm (0.88 g·cm^{-3}). As expected, oven dry density was higher, but influence of the diameter class was comparable to the basic density. The radial distribution of density can be resolved from Fig. 1a, b and c). The density at pith is lower than the density at the middle part, predominately due to the fact that the chemical composition of pith is different, due to fast growth at the beginning. The middle part has higher density than the part close to the bark, as the sapwood has lower density than¸ the heartwood, as well (Fengel and Wegener 1989). The reason for this occurrence is presence of secondary metabolites in heartwood, that influences the density. Density influences, a lot of wood properties. But there was no influence determined between density and volumetric shrinkage (β_V) or swelling (α_V). As the correlation between swelling and shrinkage is almost 100%, only shrinkage is discussed. The highest shrinkage was determined at oak samples from the smallest diameter class (14.15%). And the lowest one at wood coming from the wood of the biggest diameter (11.32%) (Figs. 2a, b and c). These data indicates, that wood coming from older and thicker trees is more dimensionally stable. If the radial distribution of dimensional stability is considered, the highest dimensional stability can be find at recent softwood (bark). The most challenging material from the perspective of dimensional stability is pith part coming from the trunks of the smallest diameter class (10-20 cm). The reason for this occurrence might be the fact that juvenile wood in the youngest trees was not completely transformed to heartwood.

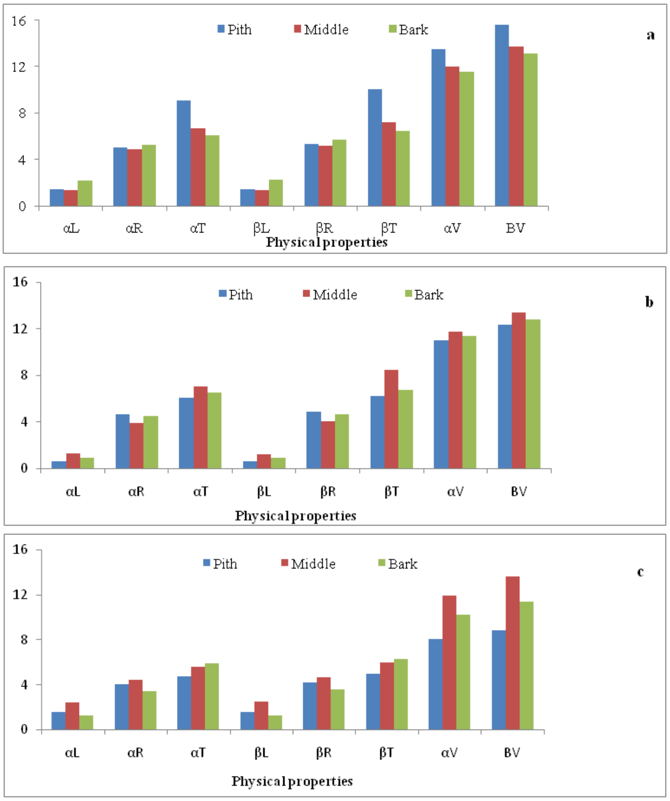

Fig. 2: Influence of the three diameters on the physical properties of oak wood.
α_L: longitudinal swelling, α_R: radial swelling, tangential swelling, β_L: longitudinal shrinkage, β_R: radial shrinkage, β_T: tangential shrinkage g, α_V: volumetric swelling, β_V: volumetric shrinkage.

The dimensions of the cells was comparable at all of the samples investigated Fig. 3 a, b and c. Fiber length varied between 0.82 (Dia. Class 10-20 cm, middle part) to 1.01 (Dia. Class 20-30 cm, bark). With exception of the samples made of tree with the smallest diameter, fiber length increases from pith to the bark. Fiber diameter (FD), lumen width (LW) and cell wall thickness (CWT) are parameters that are somehow connected. Cells with smaller lumen, has more thick cell walls. However, dimensions of the cells are quite comparable. These dimensions are in line with the data from the literature for other oak species (Fengel and Grosser 1976).

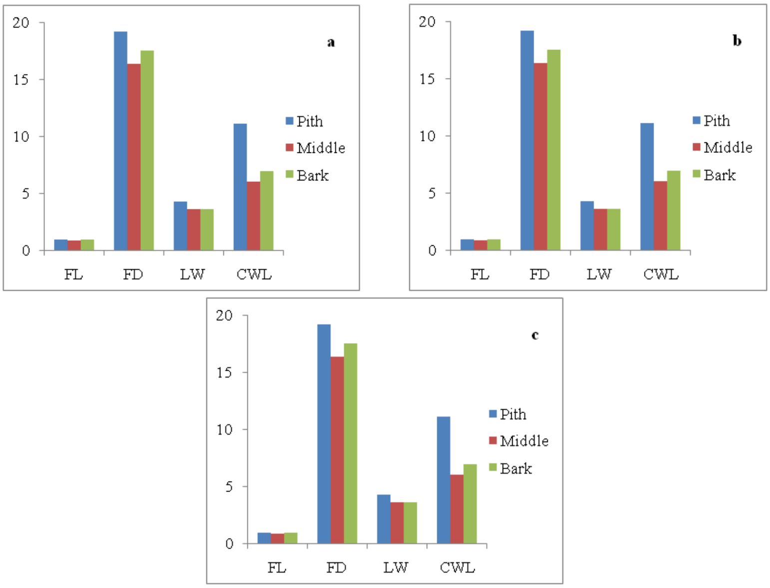

Fig. 3: Influence of the three diameters on the biometrical of oak wood.
FL: fiber length, FD: fiber diameter, LW: lumen width, CWL: cell wall thickness.

Chemical composition is one of the most important factor that indicates the performance of the respective wood species. As reported by Fengel and Wegener (1989), oak wood species (*Quercus* sp.) contains 37.6% of cellulose, 24.5% of lignin and 4.4% of extractives. Predominately extractive content at oak wood can vary a lot, depending on growth conditions, ring width, density (Humar et al. 2008). As can be seen from Fig. 4, cellulose content (39% - 45%) in Persian oak is a bit higher than reported for the reference oak wood species. With increasing diameter, the cellulose content is increasing. For example, at the diameter class 10-20 cm, cellulose content was 39%, while at the most thick trees (30-40 cm), cellulose content reaches 45%. In contra tary to the cellulose, lignin content decreases with increasing diameter.

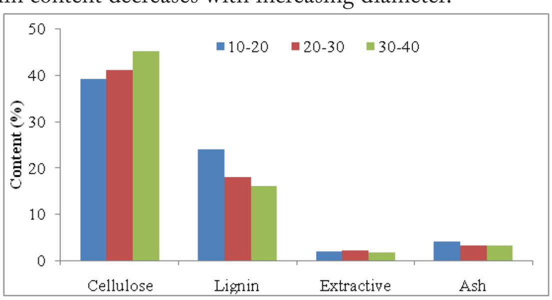

Fig. 4: Influence of the three diameters on the chemical composition of oak wood.

However, ash and extractive content in Persian oak was quite constant. But the extractive content of Persian oak, was rather low. For the English oak, much higher extractive content are reported. Extractive content in English oak can reach 6% (Humar et al. 2008). On the other hand, ash content was quite high (3.2%-4.1%). Reference data for ash content at oak are much lower (0.3% -0.5%) (Fengel and Wegener 1989, CEN/TS 14961, 2005). Such high ash content could cause toll wear problem during processing. Such high ash content is not typical for temperate wood species. The highest literature data for ash content are reported for iroko (*Milicia excelsa*) (3.4%) (Fengel and Wegener 1989).

CONCLUSIONS

This study examined the influence of age tree on wood biometry, physical and chemical properties of Persian wood in southwest of Iran. The results of wood properties are summarized as follows:

1. The density of the Persian oak is quite high, ranging from 0.85 $g{\cdot}cm^{-3}$ to 1.01 $g{\cdot}cm^{-3}$. On the other hand, the density at pith is lower than the density at the middle part due to the pith is consisting of juvenile wood.
2. The highest shrinkage was determined at oak samples from the smallest diameter class (14.15%) and the lowest one at wood coming from the wood of the biggest diameter (11.32%), indicating older and thicker trees is more dimensionally stable.
3. Fiber length varied between 0.82 (Dia. Class 10-20 cm, middle part) to 1.01 (Dia. Class 20-30 cm, bark). Moreover, fiber length increased from pith to the bark.
4. With increasing diameter, the cellulose content increased and the lignin content decreased while ash and extractive content was quite constant.

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