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Note

Physical properties of walnut limbs**

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A b s t r a c t. Physical properties of walnut limbs were measured. The moisture content and density were found to be 51.32% (d.b.) and 953.14 kg m^{-3}, respectively. The average values of modulus of rupture and the bending modulus were also obtained as 69.73 and 6325.44 MPa, respectively. The average value of toughness in impact test was 3.94 kg m.

K e y w o r d s: bending resistance, impact resistance, hardness

INTRODUCTION

Walnut tree is really ancient in Iran. Walnut production in Iran was 170 000 t in 2002 and ranked fourth among other countries (Anonymous, 2009). Investigating physical and mechanical properties of walnut tree is required for engineers and designers of harvesting machines to find out design limitations. Keramat Jahromi *et al*. (2009) studied the mechanical properties of date palm to design a climber. The results were used for designers of climber machines and robots. After evaluating the resistance of main stems of date palm, Shamsi and Mazloomzadeh (2009) indicated that maximum stress in the range of 7 to 197 is less than the failure stress of the tree. A study showed that there is a significant relationship between tensile stress of alfalfa stem and its relative moisture (Nazari Galedar *et al*., 2009). Many studies have been done to elucidate mechanical properties of different kinds of wood (including walnut), but most of them concerned dry woods used in wood and paper industries (Korkut and Guller, 2008; Lionetto and Frigione, 2009; Niklas, 1997). Vibrational characteristics of shakers and trees are of importance for better shaker components designing. The information could result in maximum efficiency of harvesting and minimum damage levels through the application of appropriate vibration to the tree (Adrian and Fridley, 1965). According to the literature, the latter is one of the most important issues in fruit and nut harvesting (Horvath and Sitkei, 2004; Láng, 2008; Rosa *et al*., 2005). Currently, simulation of tree shaking by mechanical harvesters is possible, provided that the physical and mechanical properties of both tree and shaker are available. In Iran, the need of using machines to harvest walnut fruit has made mechanization essential.

The aim of this paper was to show the physical properties of walnut tree and its fruit.

MATERIALS AND METHODS

Samples for the study were obtained from main limbs of 15 year-old walnut trees in the gardening research centre of University of Tehran, Iran. In order to prevent any changes in moisture content of the samples, they were covered with nylon. The pieces of wood were cut down according to the standard sizes for each experiment. Then, the samples were tested in a wood mechanical property lab at the temperature of 23-27°C and moisture content of 50%. Moisture content of samples was determined by AOAC (1984) procedure. Density of samples was determined by measuring the mass of 2×2×2 cm^3 samples divided by the sample volume. The balance used was SKY-600 model with an accuracy of 0.01 g.

Bending resistance and hardness tests were carried out using an Instron machine (model 4486, UK). Its minimum and maximum capacity of load cell in these tests was 10 kN. All mechanical tests were done according to ASTM (2000). The number and dimensional size of the sample in bending resistance test were 18 and 2×2×28 cm^3, respectively.

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T a b l e 1. Mechanical properties of green walnut tree limbs (number of specimens is 18)

Values	Displacement at yield (mm)	Strain at yield (mm mm^{-1})	Load at yield (kN)	Modulus of rupture (MPa)	Young's modulus (MPa)	Force$_{max}$ for hardness test (kN)	Energy for impact test (kg m)
Mean	14.18	0.03	1.49	69.73	6325.4	1.75	3.94
SD	3.97	0.01	0.27	12.47	1383.3	0.33	1.56
Min	6.64	0.01	1.05	49.41	2407	1.14	1.8
Max	22.03	0.04	2.13	99.80	8152	2.17	5.4

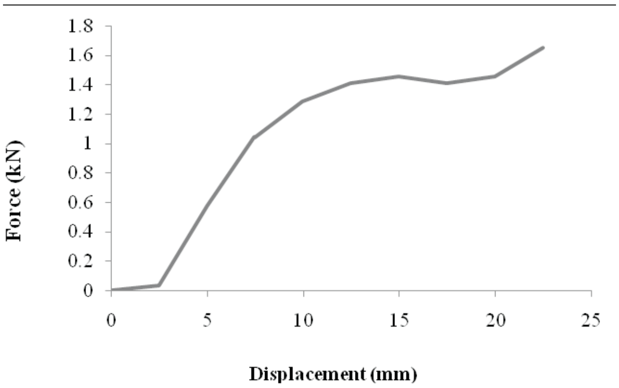

Fig. 1. Load-distance graph for bending resistance test.

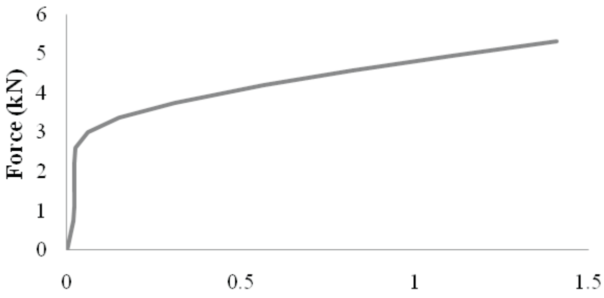

Fig. 2. Load-distance graph for hardness test.

Samples were put on two fixed pillars which were 44 cm far from each other. Loading speed for each sample was set to exactly 10 mm min^{-1}. When the displacement graph became horizontal, loading would stop. At that time a weak sound was heard due to the fracture.

Sample sizes provided for hardness test were 5×5×15 cm^3. A cylinder with 11.3 mm diameter and 6 mm min^{-1} velocity was used. Loading continued until metal cylinder penetrated into the sample as far as the value of its radius. There were 18 samples in this test.

Impact residence test was conducted by means of impact measuring machine (Alfred J. Amsler and Co. Switzerland) with capacity of 10 kg m^{-1}. Dimensions of samples for impact resistance test were 2×2×28 cm^3. This machine had two legs for holding the sample. Distance between the legs was about 24 cm. The hammer was set free in such a way that it hit exactly the centre of the sample.

RESULTS AND DISCUSSION

The average values of moisture content and density of the samples were 51.32% (d.b.) and 953.14 kg m^{-3}, respectively. The results of bending resistance test, hardness test and impact test for 54 samples are given in Table 1. In the bending resistance test, the average amount of displacement, strain, yield load, modulus of rupture and bending modulus were 14.18 mm, 0.03 mm mm^{-1}, 0.488 kN, 69.73 MPa, 6 325.44 MPa, respectively. The results of hardness and impact tests showed that the average maximum load and energy were 1.75 kN and 3.94 kg m, respectively. Figure 1 shows the ratio of displacement to load changes for average behaviours of 18 samples. Figure 2 shows the relationship between the force applied in the hardness test and displacement. Recognizing limitations for designing a compatible shaker of walnut tree is the only purpose of this study. The bending resistance test not only shows the range of maximum load to limbs of trees during shaking a tree, but it also determines the bending resistance of main limbs, which is important for modelling the vibrant behaviour of the shaker and for simulation of a shaking tree. In most existing shakers, it is better to use a clamp for transferring vibration to the tree. Clamps usually use hydraulic or pneumatic load to clamp the trees, but if it is not controlled, it damages the tree. The hardness resistance test helps the shaker designer to understand the range of applied load during grasping the limbs.

CONCLUSIONS

1. Average values of modulus of rupture and Young modulus in bending test were found to be 69.73 and 6 325.44 MPa, respectively.

2. The maximum load in the hardness test was 1.75 kN.

3. The average value of toughness was 3.94 kg m^{-1} in the impact test.

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