Physical and mechanical properties of Oak (*Quercus Persica*) fruits

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Abstract: This research was conducted over one Iranian variety of Oak (*Quercus Persica*) with 70 observations. Physical and mechanical properties of oak are necessary for equipment used in activities such as transportation, storage, grading, packing etc. Properties which were measured include fruit dimensions, mass, volume, projected area, fruit density, geometric mean diameter, sphericity and surface area. Bulk density, porosity and also packing coefficient were measured. Experiments were carried out at moisture content of 51.8% (w.b.). Results showed that average mass and volume were 12.95 g and 10.27 mL, respectively. Dimensions increased from 41.85 to 61.09 mm in length, 14.45 to 25.02 mm in width and 14.42 to 24.38 mm in thickness. The mean projected area perpendicular to length, width and thickness obtained 433.91, 1,085.48 and 1,115.46 mm^2, respectively. The geometric mean diameter and surface area were calculated as 27.638 mm and 2,423.82 mm^2, respectively, while sphericity was measured 51.78%. Elasticity modulus (E), maximum force which fruit can support (F_{max}) and work which performed to this force have been determined.

Keywords: physical and mechanical properties, oak, postharvest, *Quercus Persica*

Citation: Jalilian Tabar F., A.N. Lorestani, R. Gholami, A. Behzadi, and M. Fereidoni. 2011. Physical and mechanical properties of Oak (*Quercus Persica*) fruits. Agric Eng Int: CIGR Journal, 13(4).

1 Introduction

The oak (*Quercus persica*) is widely distributed throughout the western Iran States and is an important source of wood and fiber. Fruit of this tree (shown in the Figure 1) has great characteristics such as medical and nutritional. Oak fruit include starch, protein, oil and tannins. This fruit is useful in treatment of anemia, diarrhea, etc, and the other one application is livestock feeding.

Many studies have been reported on the physical, mechanical and nutritional properties of fruits, such as fresh okra fruit (Owolarafe and Shotonde, 2004), cherry laurel (Calisir and Aydin, 2004), *Juniperus drupacae* fruit (Akinci et al., 2004), wild plum (Calisir et al., 2005), gumbo fruit (Akar and Aydin 2005), African nutmeg (Burubai et al., 2007) and berries (Khazaei and Mann, 2004). But no detailed study concerning the physical and mechanical properties of oak fruit was found in the literature.

From among the physical specifications of agricultural product: mass, volume and centre of gravity are of high importance in sizing systems. Parameters measurable through sizing systems are: dimensions (length, width, and height), surface area and weight, physical and mechanical properties.

Figure 1 Oak fruit

Received date: 2011- **Accepted date:** 2011-

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2 Materials and methods

2.1 Sample preparation

70 oak fruits are prepared from area in the Zagros Mountains near Kermanshah. This fruit was kept in 25℃ in the laboratory.

2.2 Physical properties

The three major dimensions, as, length, width and thickness were measured by a digital caliper (Sharifi et al., 2007).

The mass of each oak was measured on a digital balance with an accuracy of 0.01 g. Fruits volume by water displacement method and using a graduated cylinder has been determined.

Specific gravity of each oak fruit was calculated by the mass of oak fruit in air divided by the mass of displaced water.

To determine water content, fruit was kept in the oven for 24 h at 130℃. Water content (w.b.) of fruit was derived from Equation (1) (Lorestani and Tabatabaeefar, 2006).

$$\text{w.c.} = \frac{M_0 - M}{M_0} \quad (1)$$

where, M and M_0 are last and initial (before placed in the oven) mass of fruit.

The three important characteristics that measured are maximum (P_c), mean (P_b) and minimum projected area (P_a) (perpendicular to thickness, width and length respectively). Parameters, such as coefficient of sphericity, mean geometrical diameter and packing coefficient (Mohsenin, 1986) were obtained (Topuz et al., 2004; Sharifi et al., 2007).

Geometric mean diameter (*GMD*) and sphericity were determined using the following equations (Mohsenin, 1986):

$$GMD = (abc)^{1/3} \quad (2)$$

where, *GMD* is geometrical mean diameter (mm); a is the main (longest) diameter (mm); b is the intermediate diameter (mm) and c is the longest diameter perpendicular to a and b (mm) (Topuz et al., 2005).

Sphericity (%) was calculated by following equation:

$$\text{Sphericity} = \frac{GMD}{a} \times 100 \quad (3)$$

The average area projected (known as the criterion area, Ac, mm^2) was determined from Equation (4):

$$\text{Criteria areas (CPA)} = \frac{(P_a + P_b + P_c)}{3} \quad (4)$$

Surface area was obtained as:

$$S = \pi\ GMD^2 \quad (5)$$

where, S is surface area (mm^2); *GMD* is geometrical mean diameter (mm) (Topuz et al., 2005).

Coefficient of packaging was obtained as:

$$\lambda = v/v_0 \quad (6)$$

where, v is volume of fruit present in the carton (mL); v_o is volume of the carton (mL) (Topuz et al., 2005).

The bulk density was determined using the mass volume relationship (Fraser, Verma, & Muir, 1978) by filling an empty plastic container of predetermined volume and weight. The fruits were poured from a constant height, striking off the top level and weighing. The density ratio is the ratio of mass density to bulk density expressed as percentage while porosity (P) was computed (Owolarafe et al., 2004) as:

$$P = \frac{\rho_t - \rho_b}{\rho_t} \times 100$$

where, ρ_t is true density and ρ_b is bulk density.

The aspect ratio (R_a) was calculated as recommended by Owolarafe et al. (2004) as:

$$R_a = \frac{b}{a} \times 100\% \quad (8)$$

2.3 Mechanical properties

Quasi-static compression tests were performed with a zowick/roell Universal Testing Machine equipped with a 500 N compression load cell and integrator (Figure 2). The measurement accuracy was 0.001 N. Elasticity modulus (E), maximum force which fruit can support (F_{max}) and work which performed to this force have been determined. The individual oak fruit was loaded between two parallel plates of the machine and compressed at preset force condition until rupture occurred as is denoted by bio-yield point in the force-deformation curve. The bio-yield point was detected by a break in the force deformation curve. Once the bio-yield was detected, the loading was stopped. The mechanical properties of oak fruit were expressed in terms of rupture, deformation and toughness required for initial rupture. Oak fruit rarely broken at this rang, so, this show that oak fruit are strength.

Spreadsheet software, Microsoft EXCEL 2007, was used to analyze the data.

Figure 2 Zowick/roell universal testing machine

3 Results and discussion

A summary of the descriptive statistics of the various physical dimensions is shown in Table 1.

Table 1 Measured parameters

Parameter	max	min	mean	*SD*	*CV*/%
Length *a*/mm	61.09	41.85	53.51	4.21	7.87
Width *b*/mm	25.02	14.45	20.13	2.80	13.91
Thickness *c*/mm	24.38	14.42	19.74	2.76	13.99
Biggest projected area P_c/mm^2	1,540.60	697.71	1,115.46	206.80	18.42
Mean projected area P_b /mm^2	1,498.95	664.62	1,085.48	205.42	19.05
Smallest projected area P_a/mm^2	677.45	243.88	433.91	119.64	27.57
Mass/g	22.17	5.30	12.95	4.00	30.91
Volume/mL	17	5	10.27	2.96	28.85

The average major, intermediate and minor diameters for oak fruits were 53.51, 20.13 and 19.74 mm, respectively. The importance of dimensions is in determining the aperture size of machines, particularly in separation of materials, as discussed by Mohsenin (1978).

The *GDM*, with an average value of 27.63 mm, varied between 14.21 and 33.02 mm. Average sphericity was obtained as 51.78%. As shown in Table 1, the volume of oak fruit varied from 5 mL to 17 mL, with an average value of 10.27 mL. Similarly, the average surface area was found to be 2,423.817 mm^2. Average projected area varied from 433.91 to 1,115.46 mm^2, with a mean value of 1,085.48 mm^2.

Elasticity modulus and other mechanical parameters were shown in the Table 3. The rupture force of oak fruit is too high so that the machine in this research was not enough to break that, while the rupture force for barberry was 47.23 N (Fathollahzadeh and Rajabipour, 2008) and pine nut 468 N (Faruk et al,. 2004). This shows that oak fruit could be store in big box and bulk. The average oak elasticity modulus of oak fruit was 0.99 GPa.

Table 2 Calculated parameters

Parameter	max	min	mean	*SD*	*CV*/%
True density/g · mL^{-1}	2.668	0.753	1.27	0.293	22.889
Geometric mean diameter GMD/mm	33.020	21.386	27.63	2.789	10.090
Sphericity/%	65.177	44.236	51.78	5.044	9.741
Surface area/mm^2	3,425.285	44.236	2423.81	484.475	19.988
Equivalent diameter/mm	33.022	21.386	27.64	2.788	10.088
Arithmetic diameter/mm	36.140	25.160	31.12	2.523	8.106
Criteria area CPA/mm^2	1,225.690	544.720	878.38	172.717	19.663
Aspect ratio/%	53.04	29.43	37.77	4.96	13.13

Table 3 Mechanical properties

Parameter	max	min	mean	*SD*	*CV*/%
Elasticity modulus/GPa	42.74	0.42	0.99	0.36	1.50
F_{max}/N	33.09	124.07	375.00	138.00	447.00
W to F_{max}/N·mm	47.97	271.11	565.11	172.25	1102.35

4 Conclusions

1) Some physical properties of oak (*Quercus Persica*) were determined at a moisture content level of 51.8% (w.b.).

2) The fruit volume, major, intermediate, minor diameters, sphericity and mass were obtained as

10.27 mL, 53.51 mm, 20.13 mm, 19.74 mm, 51.78% and 12.95 g, respectively.

3) At the same moisture level, bulk density, porosity and true density were also evaluated as 0.5184 g/mL, 59.18%, 1.27 g/mL, respectively.

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