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The Determination of Some Physical Properties of *Pistachio vera* L.

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Abstract: In this study, five different pistachios (Kirmizi, Uzun, Halebi, Siirt, Ohadi), which are produced widely and have a great potential in future, were examined. Nut's stem breaking strength and cluster breaking strength of these pistachio varieties were measured during the harvesting time. Mass, volumes and sphericity of samples taken from the same garden during the storage period times of 1, 2 and 3 months were measured and each samples was cracked from different positions: Vertical (A), longitudinal with open line parallel to the horizontal (B) and longitudinal with open line to parallel to vertical (C) with two different speeds (50, 100 mm min^{-1}). Deformation and cracking force measured and cracking energy, cracking stress and modulus of elasticity were calculated and force-deformation curves were drawn. Additionally, friction resistance of fruits stored for 3 months were measured. The maximum Nut's stem breaking strength was found as 6.4 N in Ohadi variety. The relationship between the cracking force of nuts and variety, storage time, direction of cracking, cracking speed were found statistically significant. Minimum and maximum cracking force of nuts were found 287 N, 336 N in Uzun and Siirt varieties, respectively. The method of cracking position (C) that is the most commonly used by producer created the least cracking resistance, in addition to position, cracking resistance was decreased more with cracking speed of 100 mm min^{-1}.

Key words: *Pistachio vera* L., physical properties, harvesting criteria

INTRODUCTION

The Pistachios is grown in the 30-45 parallel of the north and south hemispheres. Turkey is the one of the big producing countries in the northern hemisphere. Especially, the south-east part of Anatolia is the central genetic centre of this species. Turkey is the third largest producer of *Pistachio vera* L. in the world with an annual production about of 35, 000 t. (Anonymous, 2001) (Table 1).

Pistachio vera L. can be mostly consumed as appetizer. It has high level nutritional value as protein, carbonhydrate and some vitamins and minerals (Anonymous, 2001) (Table 2).

Despide the previous importance of pistachio vera, in the World Trade, mechanization of harvest and postharvest of *Pistachio vera* L. are not available. In order to design equipment for harvest and postharvest, it is necessary to determine the physical properties of *Pistachio vera* L. It is also important to carefully recognize the mechanical properties of the agricultural product.

The compression tests of biological materials provide an objective method for determining the mechanical properties in quality evaluation and control, the maximum allowable load for minimum mechanical damage. (Mohsenin, 1986). It is possible to determine compresive properties by using the force-deformation curve.

Table 1: *Pistachio vera* L. production in the world (Anonymous, 2001)

Annual production	Years	Iran	USA	Turkey	Syria	Greece	Italy
	1988	81.540	42.600	14.980	17.870	2.990	270
	1989	31.751	17.960	35.017	15.785	4.898	3.265
	1990	90.720	54.430	13.970	19.950	2.630	270
	1991	36.288	34.930	44.997	10.886	2.268	2.993
	1992	90.790	65.770	19.988	19.950	4.818	270
	1993	180.000	68.040	49.890	21.950	4.080	3.990
	1994	146.680	72.401	45.856	20.115	4.099	3.077
	1995	239.000	67.130	36.000	14.500	5.400	2.200
	1996	282.000	47.630	60.000	18.000	6.700	100
	1997	111.916	81.650	70.000	29.428	3.600	5.000
	1998	313.957	85.280	40.000	35.684	5.000	100
	1999	313.957	49.900	35.000	33.867	5.000	100

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Table 2: The nutritional value of Pistachio vera L. (Anonymous, 2001)

Edible parts of pistachio/100 g	*Pistachio vera* L.
Protein (%)	19.30
Crude oil (%)	53.70
Carbonhydrate(%)	19.00
Ca (mg)	131.00
P (mg)	500.00
Fe (mg)	7.30
K (mg)	972.00
Vitamin A (mg)	230.00
Vitamin (B1) (mg)	0.67
Vitamin (B6) (mg)	1.40
Calorie	597.00

Ozcelik *et al.* (1977) expressed that *Pistachio vera* L. fruits needs 9 kg cm energy for cracking which is equal to 35 m/s hit velocity to flat plate. This result is important for getting the split pistachio nut. Several researchers have studied on the physical properties such as shape, size, mass, bulk density, porosity, static friction coefficient on different surfaces, aerodynamic properties of some crops, fruits and vegetables (Kashaninejad, 2006; Tabak *et al.*, 2002; Sahoo and Srivastava, 2002; Ozarslan, 2002; Polat and Ulger, 2001).

The aim of this research is to determine some of the physical properties and also some harvesting criteria of *Pistachia vera* L.

MATERIALS AND METHODS

This research consist of two parts. The determination of harvesting criteria in orchards and physical properties of *Pistacio vera* L. under laboratory conditions.

Pistacio vera L. nuts are harvested two different ways; the nuts are picked from the trees by hand or after the cluster of *Pistacio vera* L. are picked by the breaking of a cluster stem, the fruits are taken from the cluster. These experiments were carried out in *Pistachio vera* Research Institute's orchards settled in Gaziantep.

In this study, the six different *Pistachio vera* L. varieties named Kırmızı, Uzun, Halebi, Siirt, Ohadi which are grown widely were used. Stem breaking strength, cluster breaking strength and the correlation between stem breaking strength of *Pistachio vera* L. nut and nut's mass, correlation between cluster breaking strength and diameter of the cluster's stem were examined.

The stem breaking strength of *Pistachio vera* L. nuts on the four different sides of trees using two portable dynamometer (chatillon) readings min 25 g to max 2.5 kg and min 100 g to max 14 kg were measured. These measurements for each all varieties and four different sides of the trees on 50 of the samples were carried out separately. The correlation between nut's stem break off and mass of fruit for 100 samples and also the correlation between the cluster's break off and the dimeter's of cluster's stem for 30 samples were determined.

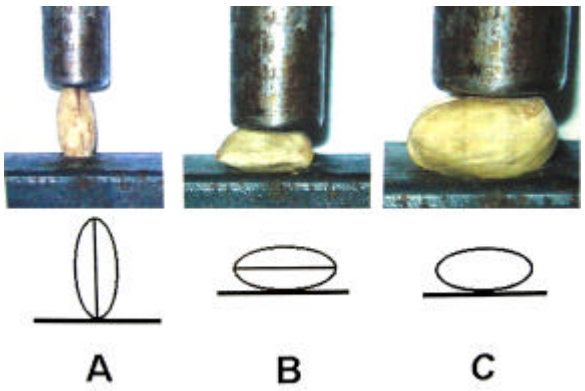

Fig. 1: Three different direction of *Pistachio vera* L. nuts

The ratio of the nut's mass and breaking strength was computed using the equation (Gezer, 1997)

$$k = m/R \quad (1)$$

k = the ratio
m = mass (g)
R = Breaking stress, N

During the measurement of the cluster's strength, in order to stop the bending of the stem some special stabilizing clamp were tied to stem of cluster.

Pistachio vera L. nuts just after harvesting were sorted, loaded into refrigerated storage for 1, 2 and 3 months. Mass, volumes, sphericity of samples, dimensions, static friction coeffiency, modulus of elasticity, cracking stress, cracking energy of samples taken from the same garden during the just after harvest and the storage times 1, 2 and 3 months were determined. Each of the samples was cracked three different directions (Fig. 1) vertical (A), longitudinal with split line parallel to the vertical (B) and longitudinal with split line parallel to vertical (C) with two different speeds (50, 100 mm min^{-1}) by using force-deformation apparatus which consists of HBM-Q3 dynamometer, HBM-W model LVDT. Cracking energy, cracking stress, moduls of elasticity for 20 *Pistachio vera* L. samples were determined separately.

The moduls of elasticity was determined by using the stress-stain curve.

Cracking stress (σ) was calculated by Eq. (2)

$$\sigma = \frac{F}{A} \quad (2)$$

According to the cracking direction contact areas were determined with a different equation.

Contact area (A) for vertical cracking direction;

$$\text{Contact area} = \Pi \frac{(\text{width})^2}{4} \quad (3)$$

Contact area (A) for horizontal cracking direction

$$\text{Contact area} = \Pi \frac{(\text{length} \times \text{width})^2}{4} \quad (4)$$

Cracking Energy was calculated from the area of force-deformation curve (Burden and Faires, 1989)

$$\text{Energy} = \int_a^b F(x)\, dx \quad (5)$$

F : Force
dx : Displacement
a = The point where force value equals zero
b = Cracking point

The each of the nuts, varieties, in each the forms, dry red shelled, roasted nuts and fresh nuts, 50 samples were separately and randomly selected and labeled. Length, width and thickness were measured by calliper accuracy to 1/10. These nuts were weighed by means of an electronic balance scale.

The determination of volume and density of agricultural products is important for many procedures such as drying, storing, separation from the other materials, grading, maturity evaluation.

Volume can be determined by the water displacement technique and also the resembling technique of geometric shapes.

$$V = \frac{w_1}{\gamma} \quad (6)$$

w_1 = weight of displaced water
γ = density of water

The degree of sphericity of pistachio nuts and kernels were calculated by the following equation (Mohsennin)

$$\phi = \frac{(LWT)^{\frac{1}{3}}}{L} \times 100 \quad (7)$$

Static and sliding coefficiency of friction of agricultural product on different materials are very important to design engineers, prediction of motion of materials on handling and harvesting equipment. This is also needed to design the angle of sieves and determining the pressure of product against the bin walls. The friction coefficiency depends on the moisture and shape characteristics of the nuts and also the structures of surface (Evcim, 1991; Yaciolu, 1996).

The coefficiency of static friction on different surfaces namely, aluminium, polyethylene, rubber, polyesther, galvanised iron, canvas, stainless steel were determined by using the inclined plane method. Before these measurements, the nuts were put on the inclined surfaces, then the surface's slope was increased gradually with a screw device until the nut started to move downward, the angle of tilt was read and the tangent of angle calculated. This measurement was repeated for 10 samples of the dry red shelled nuts, kernels and roasted nuts of the each of the varieties on the eight different surfaces.

RESULTS AND DISCUSSION

These experimental values were evaluated by a completely randomized design. The SPSS 10.0 statistical program was used.

Harvesting criteria: The results of the variance analysis related to the effects of *Pistachio vera* L. varieties and the sides of trees on the Nut's stem breaking strength are given in Fig. 2.

According to F-test, the differences between the effects of *Pistachio vera* L. varieties and the sides of trees on the Nut's stem breaking strength and interactions between varieties and sides of trees were found statistically significant. Ohadi variety had a maximum breaking strength of 6.4 N, Uzun variety had a minimum breaking strength of 1 N (Fig. 3).

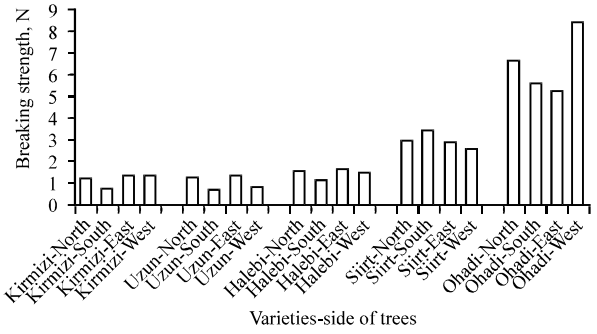

Fig. 2: The effects of *Pistachio vera* L. varieties and the sides of trees on the Nut's stem breaking strength

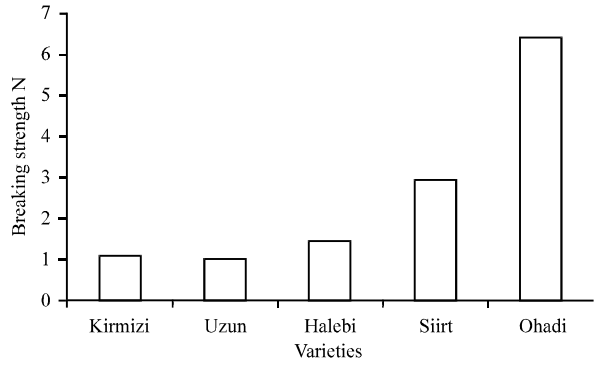

Fig. 3: The stem breaking strength of *Pistachio vera* L. nut

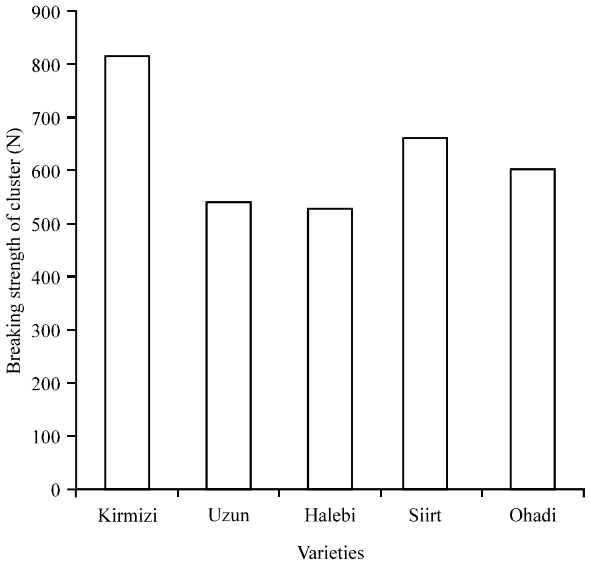

Fig. 4: The breaking strength of clusters

As to the effects of sides of trees, maximum breaking strength at the west side of the tree and minimum breaking strength at the south side of tree were found 2.88 and 2.27 N, respectively (Ozden, 2002).

Nut's stem breaking strength and mass of nuts: The ratio of m/R of the varieties was found statistical significant. When this ratio is higher than 1, nuts can be harvested by a harvesting machine such as different kinds of shaker. The maximum ratio in Halebi and minimum ratio in Ohadi varieties were obtained as 2.64 and 0.77 g N^{-1}, respectively.

The correlation between breaking strength of cluster and the diameter of cluster: Breaking strength of cluster of Kırmızı, Ohadi, Siirt varieties were effected and increased by increasing of the stem diameter of cluster. This correlation was not found statistically significant for Uzun variety. The Breaking strength of clusters for each varieties are given in Fig. 4 There was a linear relation between diameter of stem and breaking strength.

Table 3: The dimension of *Pistachio vera* L. varieties

	Varieties	Average	Standard Deviation	Minimum	Maximum
Length (mm)	Kırmızı	23.5960	1.7035	19.60	27.30
	Uzun	22.3240	1.1074	20.00	24.90
	Halebi	21.7680	1.0255	18.60	24.90
	Siirt	27.2000	1.2349	23.30	29.70
	Ohadi	23.0440	1.0986	20.80	24.80
Width (mm)	Kırmızı	13.5700	0.7363	11.70	15.10
	Uzun	12.5700	0.6018	11.30	14.80
	Halebi	12.5040	0.6749	11.60	16.00
	Siirt	14.9960	0.5707	13.70	16.00
	Ohadi	15.6760	0.6778	14.70	17.80
Thickness (mm)	Kırmızı	12.3420	1.0610	10.20	14.30
	Uzun	10.9120	0.5302	9.90	12.20
	Halebi	11.7760	0.5196	11.00	13.20
	Siirt	14.3340	0.8893	12.10	16.70
	Ohadi	16.0180	0.6645	14.20	17.40
Mass (g)	Kırmızı	1.9762	0.3453	1.20	2.65
	Uzun	1.5344	0.1436	1.09	1.85
	Halebi	1.5288	0.1779	1.09	2.06
	Siirt	2.6806	0.3314	1.86	3.54
	Ohadi	2.7700	0.2814	2.19	3.30
Volume (mm^3)	Kırmızı	3135.7026	579.7135	1883.01	4231.70
	Uzun	2409.8900	265.9576	1836.90	2953.76
	Halebi	2520.9416	264.2250	2036.23	3135.64
	Siirt	4611.0180	585.2210	3164.81	6040.86
	Ohadi	4555.1456	490.8915	3646.89	5544.19
Sphericity (%)	Kırmızı	56.0267	7.3337	39.78	70.47
	Uzun	45.7585	3.6277	39.00	55.25
	Halebi	49.1265	4.0227	44.00	61.87
	Siirt	71.7775	6.7295	57.34	89.07
	Ohadi	83.7725	6.1329	71.00	98.56

Nut's dimensions: Maximum volume of Siirt as 4611 mm^3, minimum volume of Uzun as 2409 mm^3, maximum mass of Ohadi as 2.77 g, minimum mass of Halebi as 1.5288 g, high sphericity in Ohadi were determined (Table 3).

Force and deformation: The relationship among varieties, storage period, cracking speed, maximum cracking force, maximum deformation, maximum cracking energy, maximum stress and modulus of elasticity were evaluated by using completely randomized statistical analysis.

The following results were found: Maximum cracking force (336 N) in Siirt, minimum cracking force (287 N) in Uzun, maximum cracking energy in Siirt (246.319N mm), minimum cracking stress in Ohadi (1.772 N mm^{-2}), maximum cracking stress in Kirmizi (3.193 N mm^{-2}).

Siirt variety has maximum cracking energy which is very flexible and very difficult to be cracked. Maximum modulus of elasticity in Kırmızı of 48.738 MPa, minimum modulus of elasticity in Ohadi of 27.308 MPa (Fig. 5).

Maximum cracking force was obtained in the third storage period as 329 N. The cracking force was effected

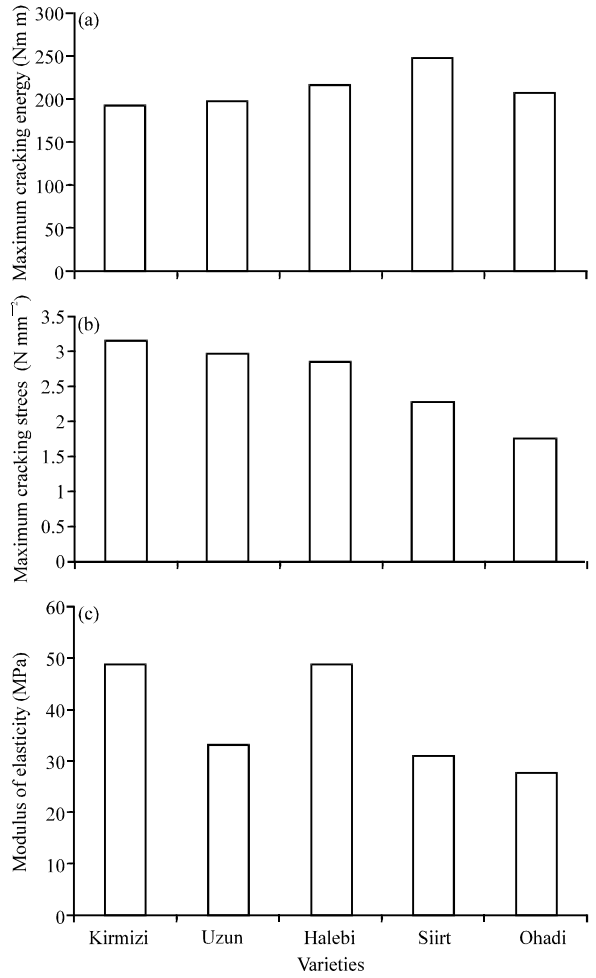

Fig. 5: The relationship between varieties and maximum cracking energy (a), maximum cracking stress (b), modulus of elasticity (c)

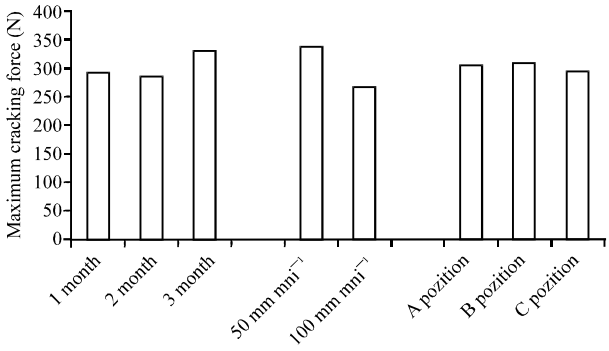

Fig. 6: The effects of the positions of nuts and cracking speed on the maximum force

by cracking speed. The decrease in cracking force with increase of cracking speed occurred as shown in Fig. 7. Two different cracking speeds (50, 100 mm min^{-1}) were

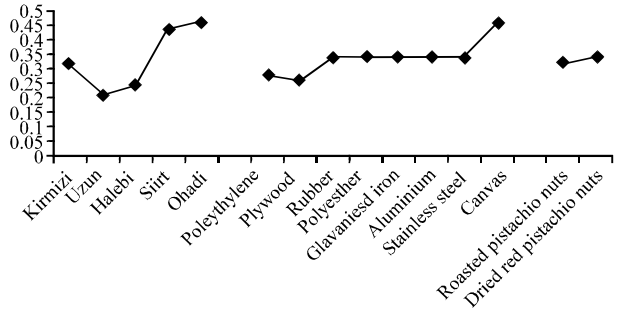

Fig. 7: The friction coefficiency of different varieties on the different surfaces

applied to nuts, a minimum cracking force of 267 N was measured at 100 mm min^{-1} cracking speed.

Cracking forces were applied on three different directions of the nuts. Generally, the workers who split the nuts by using hand apparatus, prefer C position of nuts. The results of our experiments show that the best position for the cracking of nuts with minimum force is C (Fig. 6).

The relationship between varieties and friction coefficiency: the coefficiency of friction resistance of red dried shelled nuts, roasted nuts on the aluminium, polyethylene, rubber, polyesther, galvanised iron, canvas and stainless steel were determined. Highest static friction coefficiency in Ohadi and on the canvas (TS 10978- Type1) were measured (Anonymous, 1993) (Fig. 7).

CONCLUSION

According to our pre experiments and observations, the moisture content of stored nuts did not change. Dry hulled nuts can be storaged for a long time. Nuts can be kept in the hull, but in the storage period insect and disease risks increase. The extension of the storage period causes the increasing of cracking strength. If it is possible, the shell should be cracked or split right after harvest. Nuts must be cracked in the position C and loaded by high speed. Generally, when the cracking force was applied to other directions to nuts, there was kernel damage.

The splitting and cracking processes were carried out by workers. These process are very difficult. Mechanization of *Pistachio vera* L. should be improved as soon as possible.

NOTATION

k = The ratio
m = Mass (g)

R = Breaking stress, N
σ = Cracking stress
F = Cracking force (N)
A = Contact area (mm^2)
dx = Displacement
a = The point where force value equal to zero
b = Cracking point
ϕ = The angle of response
H_c = Highest of cone (mm)
H_p = Height of platform (mm)
D_p = Diameter of platform (mm)
ϕ = The degree of sphericity
L = Length of fruit (mm)
W = Width of fruit (mm)
T = Thickness of fruit (mm)
w_1 = Weight of displaced water (g)
γ = Density of water (g cm^{-3})

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