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Some Physical and Mechanical Properties of Pistachio Nut

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Abstract

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In this study, some mechanical and physical properties of pistachio nut and its kernel (*Pistacia vera* L.) grown in South East Anatolia region were determined. Physical and mechanical properties of pistachio nut and its kernel such as dimensions, weight, thickness, geometric mean diameter, sphericity, bulk density, porosity, projected area, fruit mass, terminal velocity and static coefficient of friction were evaluated as functions of moisture content. Some physical properties of pistachio nut and its kernel such as average length, width, thickness, the geometric mean diameter, unit mass, projected area, sphericity, porosity, true density, bulk density and terminal velocity were evaluated as functions of moisture content. At a moisture content of 7.1% (w.b.) these values for pistachio nut fruit were found as 19.6, 10.1, 11.3, 13.0 mm, 1.24 g, 132.6 mm^2, 82 %, 64 %, 1109.8 kg/m^3, 488.2 kg/m^3 and 5.81 m/s respectively. The corresponding values for pistachio nut kernel were 15.7, 7.3, 7.9, 9.6 mm, 0.56 g, 47.7 mm^2, 81 %, 38 %, 1076.2 kg/m^3, 508.5 kg/m^3 and 6.26 m/s respectively. In addition, the static coefficient of friction of pistachio nut and its kernel were evaluated as functions of moisture content. The static coefficient of friction of pistachio nut and its kernel was highest for rubber and least for galvanized metal at the two different moisture content.

Key words: Pistachio nut, Kirmizi, Kernel, Physical and nutritional properties

Introduction

Pistachio nut (*Pistacia vera* L.) is the only edible crop of 11 species in the genus *Pistacia* and it is one of the popular tree nuts. Several species of the genus *Pistacia* are referred to as pistachio, but only the fruits of P. vera attain a large enough size

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to be acceptable to consumers as edible nuts (Shokraii and Esen, 1988; Ak, 1992). Pistachio is cultivated in the Middle East, United States and Mediterranean countries (Kashaninejad et al., 2005). Turkey is one of the biggest pistachio nut producers in the world with 60 000 t production per annum and 11.97 % world market share (FAO, 2005).

The pistachio nut kernel is consumed as supplied to the chocolate, ice-cream, pastries, baklava, candies, cake industry and snack foods. Firstly, pistachio nuts arrive at the processing plant after harvesting and storage, then the following process are conducted: storaging, dehulling, seperating from hull, trash, foreign materials and blank nuts, washing, drying, splitting or breaking, roasting and packaging. In order to optimize the threshing performance, pneumatic conveying, storage, drying, packaging and other processes of pistachio nut, its physical and nutritional properties must be known. Designed equipment without unknown these properties into consideration may yield poor results. Some shape and chemicial properties of Kirmizi pistachio nut variety was determined by Ak and Acar (1998), such as nut shape; elongated, nut color; dark ivory, hull dehiscence; non-dehiscent, hull tip; pronounced, hull color; red-purple group, hull colour homogen?ty; yes, split nuts 67%, suture opening; narrow, kernel flavour; satisfactory, kernel colour; yellowish, oil content; 58.89%, protein content; 24.77%.

In recent years, some studies have been carried out on physical nutritional properties for various nuts, grains and seeds such as hazelnuts (Aydin, 2002; Ozdemir and Akinci, 2004), garlic (Haciseferogullari et al., 2005), hackberry (Demir et al., 2002), shea kernel (Olajide et al., 2000), Chick pea seeds (Konak et al., 2002), soybean (Dehspande et al., 1993), Balanites Aegyptiaca nuts (Aviara et al., 2005), cashew nut (Balasubramanian, 2001), arecanut (Kaleemullah and Gunesakar, 2002), plum cultivars (Ertekin et al., 2005), myrtle fruits (Aydin and Ozcan, 2006), wet dehulled niger seed flour (Bhagya and Sastry, 2004), sunflower (Kayisoglu et al., 2004) and Filbert Nut and Kernel (Pliestic et al., 2006). A number of researches have conducted studies on different pistachio nut varieties but there have been any studies related to the selection of Kirmizi pistachio nut and its kernel. (Ghazanfari et al., 1996; Kashaninejad et al., 2005; Pearson and Slaughter, 1996; Hsu, Mannapperuma, and Singh, 1991).

There were two objectives of this study. The first was to investigate both the physical and mechanical properties of Kirmizi pistachio nut varieties widely grown in the pistachio nut plantations of Turkey. The second objective was to determine a convenient reference table with physical and mechanical information suitable for pistachio nut mechanisation and food processing.

Material and Methods

Material

"Kirmizi" is one of the major varieties which is produced in Turkey, therefore this cultivar was used in this study. Pistachio nut and its kernel at moisture levels of 7.1% and 44.5% were used for experiments of all the physical properties in this study. Pistachio nuts samples were collected during the September mounts, from Pistachio Research Institute at Gaziantep provinces in the South East Anatolia region of Turkey. Kirmizi variety is typically long oval in shape. The samples were cleaned in a cleaner air screen to remove foreign matter such as dust, dirt, stones and chaff as well as blank, broken and immature pistachio nuts. The samples were breaked and the kernel separated from the shell by hand. The initial moisture content of the pistachio nut was determined by using standard method (USDA, 1970) and was found to vary between 7.1 and 44.5 % w.b. Harvested pistachio nuts were transferred to the laboratory in polythene bags to reduce water loss during transport. The remaining samples were packed in a hermetic container and were kept in cold storage at +4 °C until analyses.

Methods

A. Determination of physical and mechanical properties

The samples of the desired moisture levels were prepared by adding calculated amounts of distilled water, thorough mixing and than scaling in separate polyethylene bags. The samples were kept at 278 K in a refrigerator for 7 days for moisture to distrubute uniformly throughout the sample. Before starting the test, the required quantities of the pistachio nuts were allowed to warm up to room temperature (Deshpande et al., 1993; Aydin, 2002; Carman, 1996). All the physical properties of pistachio nut and its kernel were assessed at moisture levels of 7.1 and 44.5 % w.b. with ten replications at each level. In this study, 50 materials in each test were used.

To determine the average size of the pistachio nut and its kernel, a sample of 100 pistachio nuts was randomly selected. The three linear dimensions of pistachio nut and kernel (Figure 1), namely, length (L), width (W) and thickness (T) of each of the 100 fruits were measured with a micrometer to an accuracy of 0.01 mm.

The geometric mean diameter D_p and sphericity of pistachio nuts and kernels were calculated by using the following relationship at each moisture level (Mohsenin, 1980)

$$D_p = (LWT)^{1/3}$$
$$\Phi = (D_p / L) * 100$$

Where L is the lenghth, W is the width and T is the thickness.

To obtain the mass, each pistachio nut and its kernel was measured by using a electronic balance of 0.001 g sensitivity.

The bulk density of nuts and kernels (the ratio of weight and volume) was determined with a weight-per-hectolitre tester, which was calibrated in kg-per-hectolitre (Deshpande et al., 1993 and Pliestic et al., 2006). The pistachio nuts were poured into the calibrated bucket up to the top from a height of about 15 cm and excess pistachio nuts were removed by strike off stick. True density (ρ_f) were measured by the liquid displacement method. Toluene (C_7H_8) was used, rather than water, because it was not absorbed by the fruits (Mohsenin, 1980; Ozdemir and Akinci, 2004)

The porosity (ε) of pistachio nuts and kernel was calculated from the bulk, and true density, using the following equation (Mohsenin, 1980):

$$\varepsilon = (1 - \rho_b / \rho_t)$$

where ; ε is the porosity in %; ρ_b is the bulk density in kg m^{-3}; and ρ_t is the true density in kg m^{-3}.

The coefficient of friction of pistachio nuts and kernels at two different moisture contents were measured using a friction device modified by Tsang-Mui-Chung, Verma, and Wright (1984) and improved

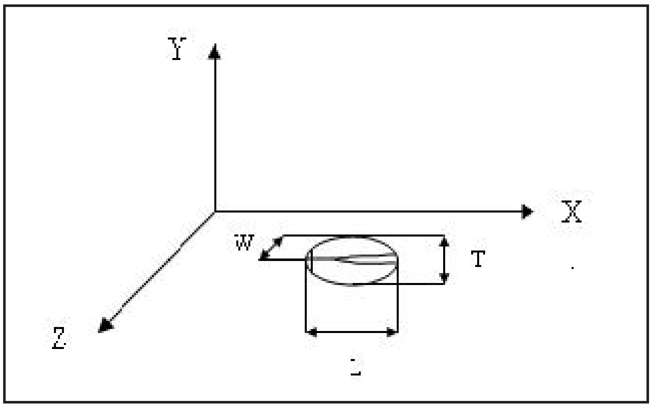

Fig. 1. Axis and three major dimensions of pistachio nut

by Chung and Verma (1989). Also, both the static and dynamic coefficient of friction with an applied torque was measured and calculated using the following relationship (Chung & Verma, 1989).

$$\mu = T_m / W \cdot q$$

Where μ is coefficient of friction, Tm measured value of torque, *q* the length of torque arm, and *W* is the weight of fruits on the rotating surface. The maximum value of torque obtained as the disk started to rotate was used to calculate of static coefficients of friction and the average value of the torque during the rotation of the disk was used to calculate the dynamic coefficient of friction. The terminal velocities (V_t) of pistachio nut and kernel at two different moisture content were measured using an air column. For each test, a sample (nut or kernel) was dropped into the air stream from the top of air column, and air was blown up the column to suspend the material in the air stream. Air was blown up the column to suspend the pistachio nut or its kernel in the air stream. The air velocity near the location of the sample suspension was measured by a digital anemometer having a least count of 0.1 m/s (Aydin and Ozcan, 2002; Gezer et al., 2002 and Joshi et al., 1993).

Result and Discussion

Physical properties

A. Dimensions, shape, density, porosity and unit mass distribution of pistachio nut and kernel

Table 1 shows the size, shape, density, porosity and unit mass of pistachio nut and kernel at two different moisture content in the range of 7.1-44.5% w.b. length, height, width and mass of pistachio nuts decreased with decrease in moisture content.

At a moisture content of 7.1, in the sample, about 45% of the pistachio nuts had a length in the range of 19-20 mm, about 80% had a width in the range of 9.0-10.6 mm and about 85% had a thickness in the range of 10.0-11.6 mm. At the same moisture content, 55% of the kernel had a length in the range of 15.0-16.0 mm, about 74% had a width in the range of 7.0-8.0 mm and about 82% had a thick-

Table 1

Dimensional properties and mass of pistachio nut and kernel

Characteristics	Mean Value							
	Nut				Kernel			
Moisture, % w.b.	7.1	S.D.	44.5	S.D.	7.1	S.D.	44.5	S.D.
Length, mm	19.6	0.89	21.4	0.81	15.7	0.76	16.8	0.84
Thickness, mm	11.3	0.61	11.8	0.44	7.9	0.61	8.7	0.41
Width, mm	10.1	0.55	11.6	0.72	7.3	0.37	8.2	0.66
Geo.mean d, mm	13	0.79	14.3	0.54	9.6	0.34	10.6	0.58
Sphericity, %	0.82	0.02	0.82	0.02	0.81	0.03	0.8	0.02
Proj. area, mm^2	132.6	5.61	109.3	7.26	47.7	2.77	56.7	3.65
Mass, g	1.24	0.08	1.95	0.09	0.56	0,03	0.81	0.06
True dens., kg/m^3	1109.8	12.21	1178.8	14.6	1076.2	9.8	1150.8	10.6
Bulk dens., kg/m^3	488.2	21.2	530.5	9.4	508.5	12.4	542.2	10.2
Porosity, %	0.64	1.2	0.68	1.1	0.36	1.2	0.39	1

ness in the range of 7.5-8.5 mm. At a moisture content of 44.5, in the sample, about 55% of the pistachio nuts had a length in the range of 20.5-22 mm, about 72% had a width in the range of 10.5-12.0 mm and about 88% had a thickness in the range of 11.5-12.0 mm. At the same moisture content, 60% of the kernel had a length in the range of 15.5-17.0 mm, about 80% had a width in the range of 7.5-8.5 mm and about 90% had a thickness in the range of 8.0-9.0 mm. The length, width and thickness of pistachio nut and kernel values were lower than hazelnut (Aydin, 2002), Balanites Aegyptiaca nuts (Aviara et al. 2005), Filbert nut (Pliestic et al., 2006) and ackee apple seeds (Omobuwajo et al., 2000), but highest than popcorns kernels (Karababa, 2005).

The average values of geometric mean diameter and sphericity of pistachio nut at a moisture content of 7.1 % (w.b.) were calculated as 13.0 mm and 82% respectively. These values for its kernel at the same moisture content were 9.6 mm and 81 %, respectively. Sphericity and geometric mean diameter of pistachio nut and kernel was lower than hazelnut (Aydin, 2002) and Filbert nut (Pliestic et al., 2006). The average pistachio nut and its kernel mass were found to be 1.21 g and 0.54 g at a moisture content of 7.1% w.b.. Whereas at a moisture content of 44.5% w.b. pistachio nut and its kernel mass were found as 1.95 and 0.81 g. These values were lower than hazelnut (Aydin, 2002), Balanites Aegyptiaca nuts (Aviara et al., 2005) and Filbert nut (Pliestic et al., 2006). At a moisture content of 7.1 % (w.b.) the true density of pistachio nut and kernel were found to be 1109.8 kg/m^3 and 1076.2 kg/m^3, while the bulk density were 488.2 kg/m^3 and 508.5 kg/m^3. Similar trend with moisture has been reported for the bulk density of hazel nuts (Aydin, 2002), amaranth seed (Abalone et al., 2004), cotton seed (Ozarslan, 2002), almond nut (Aydin, 2003), Balanites Aegyptiaca nuts (Aviara et al., 2005) and Filbert nut (Pliestic et al., 2006). The porosity of pistachio nut and its kernel decreased with increasing the moisture content. When the moisture content increased from 7.1 % w.b to 44.5 % w.b, the porosity values decreased from 64 % to 68 % and from 36 % to 39 % for pistachio nut and kernel, respectively. The values of dimensions of Kirmizi variety pistachio nuts were higher than terebinth (*P. terebinthus* L.) fruit (Aydin and Ozcan, 2002) Balanites Aegyptiaca nuts (Aviara et al., 2005) and Filbert nut (Pliestic et al., 2006).

Table 2 shows the relationship and correlation coefficients between pistachio nut and kernel dimension at different moisture content.

The relationship between length (L), thickness (T), width (W), projected area (P), geometric mean dimater (Dρ), sphericity (Φ), unit mass (M) and moisture content of pistachio nuts were given by following equations.

$L = 11.9 + 0.802\ T = 11.7 + 0764\ W = 26.8 - 0.0517\ P$

$L\ \ = 0.6 + 0.727\ D\rho = 20.0 + 0.77\ P = 16.7 + 2.47\ M = 19.3 + 0.0484\ Mc$

The relationships between the length (L) and other some properties (W, T, Dg, P, P, M) for pistachio nut can be represented by following equation:

$L = 5.78 + 0.423\ T + 0.339\ W + 0.0440\ P + 0.077\ d\rho - 4.65\ S + 2.37\ M\ \ (R^2 = 0.759)$

Mechanical Properties

Coefficients of Friction

The static and dynamic coefficients of friction of pistachio nut and its kernel was determined on three different surfaces (galvanized metal, plywood and rubber) and presented in Table 3. It is observed that the static and dynamic coefficient of friction increased with an increase in moisture content on all surfaces, for both pis-

Table 2

The correlation coefficient of pistachio nuts and kernel

Particulars	Ratio		Degrees of freedom	Correlation coefficient (R)
	7.1 w.b., %	44.5 w.b. , %		
L/H	2.01	1.185	98	0.750**
L/W	1.739	1.82	98	0.421**
L/Dg	1.505	1.502	98	0.535**
L/S	24.293	26.201	98	0.013
L/M	16.251	10.992	98	0.755**
L/P	0.148	1.196	98	0.544**
l/h	1.977	1.928	98	0.462**
l/w	2.15	2.045	98	0.419**
l/dg	1.635	1.585	98	0.185
l/s	1.191	21	98	0.169
l/m	29.047	20.594	98	0.484**
l/p	0.329	0.296	98	0.548**

** Significant at the level 1 %

Table 3
Coefficients of static and dynamic friction

Characteristics		Mean value							
		Nut				Kernel			
		7.1	S.D.	44.5	S.D	7.1	S.D.	44.5	S.D.
Coefficient of static friction	Rubber	0.45	0.06	0.52	0.13	0.43	0.02	0.58	0.04
	Plywood	0.33	0.06	0.4	0.07	0.36	0.02	0.51	0.02
	Galvanized	0.29	0.04	0.39	0.06	0.29	0.03	0.48	0.02
Coefficient of dynamic friction	Rubber	0.35	0.86	0.38	0.07	0.47	0.09	0.52	0.06
	Plywood	0.24	0.14	0.29	0.07	0.33	0.12	0.43	0.04
	Galvaniz	0.2	0.13	0.25	0.12	0.3	0.1	0.4	0.06

tachio nut and kernel. The reason for the increased static and dynamic friction coefficient at higher moisture content may be due to the water present in the pistachio nut and kernel offering a cohesive force on the surface of contact. At all moisture contents, the highest values were obtained on rubber, while the lowest values were obtained on galvanized metal for both pistachio nut and kernel.

The same trend was also observed by Gezer et al. (2002) for apricot pit, Aydin (2002) for almond nut, Ozguven and Vursavus (2005) for pea nut, Aviara et al.(2005) for Balanites Aegyptiaca nuts and Pliestic et al. (2006) for Filbert nut. The relationship between the static coefficients of friction (μ) and moisture content (Mc) of the pistachio nut and its kernel on three different surfaces are shown in Table 4.

Terminal Velocity

The terminal velocity of pistachio nut and its kernel with average mass and moisture content of the sample are reported in Table 5. The terminal velocity was found to increase from 5.81 to 8.08 in the moisture range of 7.1 and 44.5 % (w.b.), respectively. The increase in terminal velocity with increase in moisture content can be attributed to the increase in mass of an individual pistachio nut per unit frontal area presented to the air stream. The values were in the same range with corresponding values of pine nuts (Ozguven and Vursavus 2004), hazelnut (Aydin, 2002), apricot pit and kernel (Gezer et al., 2002) and pumpkin seeds (Joshi et al., 1993).

The relationship between terminal velocity of pistachio nut and kernel and average mass are shown in Table 6.

Table 4
The relationships between static coefficient of friction of pistachio nut and kernel and moisture content

Surface	Pistachio nut	Kernel
Galvanized	$\mu = 0.280 + 0.00235\,Mc$ ($R^2 = 0.89$)	$\mu = 0.263 + 0.00487Mc$ ($R^2 = 0.92$)
Polywood	$\mu = 0.310 + 0.00203\,Mc$ ($R^2 = 0.84$)	$\mu = 0.342 + 0.00380Mc$ ($R^2 = 0.89$)
Rubber	$\mu = 0.437 + 0.00196\,Mc$ ($R^2 = 0.82$)	$\mu = 0.403 + 0.00398Mc$ ($R^2 = 0.84$)

Table 5

Aerodynamic properties of pistachio nuts at two different moisture content

Characteristics	Mean value							
	Nut				Kernel			
	7.1	S.D.	44.5	S.D	7.1	S.D.	44.5	S.D.
Average mass, g	0.95	0.09	1.78	0.19	0.46	0.07	0.79	0.08
Terminal velocity, m/s	5.81	0.56	8.08	0.74	6.26	0.45	6.98	0.53

Table 6

The relationships between terminal velocity and average mass

Moisture contents, %	Mean value	
	Nut	Kernel
7.1	Vt= -1.52 + 7.70 M (R^2= 0.99)	Vt= 4.72 + 3.42 M (R^2= 0.99)
44.5	Vt= 6.47 + 0.099 M (R^2= 0.99)	Vt= 3.86 + 6.06 M (R^2= 0.99)

Conclusion

The investigations of various physical, mechanical and aerodynamic properties of pistachio nuts and its kernel revealed the following.

The average length, width, thickness and geometric mean diameter of pistachio nuts at 7.1% moisture content (w.b.) were 19.6, 10.1, 11.3 and 13.0 mm, while the corresponding values of its kernels were 15.7, 7.3, 7.9, 9.6 mm, respectively.

The average unit mass, projected area and sphericity of pistachio nut were 1.24 g, 132.6 mm^2 and 82.0%, while the corresponding values for kernel were 0.56 g, 47.7 mm^2 and 81.0 %, respectively, at a moisture content of 7.1% w.b.

The porosity, bulk and true densities of pistachio nut and its kernel increased with increase in moisture content.

The static and dynamic coefficient of friction of pistachio nut and its kernel increased with moisture content at all surfaces. This coefficient was highest on rubber, followed by plywood and galvanized metal.

As the moisture content increased from 7.1% to 44.5% (w.b.), the terminal velocity of pistachio nut and its kernel was found to increase linearly.

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