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Some engineering properties of peanut and kernel

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Abstract

Some physical properties of peanut fruit and kernel were evaluated as functions of moisture content. At the moisture content of 4.85% d.b. the average length, thickness, width, geometric mean diameter, sphericity, unit mass and volume of peanut fruits were 44.53 mm, 15.71 mm, 16.68 mm, 23.00 mm, 51.60%, 2.16 g and 5.17 cm^3, respectively. Corresponding values for kernel at the moisture content of 6.00% d.b. were 20.95 mm, 8.80 mm, 10.44 mm, 12.60 mm, 57.05%, 1.063 g and 1.14 cm^3, respectively. Studies on re-wetted peanuts showed that the bulk density decreased from 243 to 184 kg/m^3, the true density, projected area, and terminal velocity increased from 424 to 545 kg/m^3, 4.88 to 6.85 cm^2 and 7.25 to 7.93 m/s, respectively as the moisture content increased from 4.85% to 32.00% d.b.; for the kernel, the corresponding values changed from 581 to 539 kg/m^3, 989 to 1088 kg/m^3, 1.53 to 2.09 cm^2 and 7.48 to 8.06 m/s, respectively as the moisture content increased. The rupture strength of peanut and kernel decreased as moisture content increased. The dynamic coefficient of friction varied from 0.30 to 0.73 for peanut, and from 0.22 to 0.63 for kernel over different structural surface as the moisture content increased from 4.85% to 32.00% d.b.

Keywords: Peanut; Engineering properties; Bulk density; Rupture strength; Moisture content

1. Introduction

Peanut (*Arachis hypogaea* L.) is an annual crop grown predominantly in the Mediterranean region. Peanut any of several plants of hepea family having edible tubers, roots or underground seed pods, esp. The peanut edible nutlike seeds of a plant. Arachis hypogaea, of the pea family, that develops in an underground pod and has thin brownish skin. Such a pod, usually containing two of these seeds. It is widely cultivated in warm climates, and has short lived yellow flowers. The crop is an important source of protein in human nutrition and livestock feeds. The annual production of peanut in Turkey is around 85000 t and its yield ranges between 2800 and 3035 kg/ha (FAO, 2004).

At present, the crop is usually planted as second or main crop in Turkey. Harvesting and handling of the crop are carried out manually. Threshing is usually carried out on a hard floor with home made threshing machine. The knowledge of some important physical properties such as shape, size, volume, projected area, density of different grains is necessary for design of various separating, handling, optimum of threshing performance, processes of pneumatic conveying, storing and drying systems.

The major moisture-dependent physical properties of biological materials are shape and size, bulk density, true density, porosity, mass of fruits and friction against various surfaces. These properties have been studied for various crops such as cow pea (Ige, 1977); terebinth fruits (Aydin & Özcan, 2002); Almond nut fruits (Aydin, 2003); soybean (Deshpande, Bal, & Ojha, 1993); and lentil seeds (Çarman, 1996).

The object of this study was to investigate some moisture dependent engineering properties of the peanut, namely axial dimensions, unit mass and volume, sphericity, true and bulk densities, porosity, projected area, terminal velocity, rupture strength and coefficient of dynamic friction on two structural surfaces.

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Nomenclature

A	coefficient of equation	T_m	measured torque (Nmm)
B	coefficient of equation	V_t	terminal velocity (m/s)
D_p	geometric mean diameter (mm)	W	width of fruit (mm)
F_r	rupture strength (N/mm^2)	w	sample weight (N)
L	length of fruit (mm)	ε	porosity (%)
M_c	moisture content (% d.b.)	Φ	sphericity of fruit (%)
P_a	projected area of fruits (cm^2)	ρ_b	bulk density (kg/m^3)
q	torque arm (mm)	ρ_k	true density (kg/m^3)
R^2	determination coefficient	μ_d	dimensionless dynamic coefficient of friction
T	thickness of fruit (mm)		

2. Material and methods

Dried peanut were used for all the experiments in this study. The fruits were collected in 2004 during the September season at the farm of Osmaniye in Turkey. The fruits were cleaned in an air screen cleaner to remove all foreign matter such as dust, dirt, stones, chaff immature and broken fruits. The initial moisture content of fruits was determined by following standard method (USDA, 1970) and was found to vary between 4.85% and 32% d.b.

The peanut samples were prepared by adding calculated amount of distilled water, through mixing and then sealing in separate polyethylene bags in order to provide the desired moisture levels. The samples were kept at 278 K in a refrigerator for 7 d to distribute the moisture uniformly throughout the sample. Before starting a test, the required quantities of the fruit were allowed to warm up to room temperature (Çarman, 1996; Deshpande et al., 1993).

All the physical properties of the peanut were determined at moisture levels of 6%, 18% and 32% d.b. with three replications at each level.

Fifty fruits were randomly selected for a sample, in order to determine the size and shape of the fruit. For each fruit, the three principal dimensions, namely length, width and thickness were measured using an electronic micrometer with an accuracy of 0.01 mm (Fig. 1).

The geometric mean diameter (D_p) of the fruit was calculated by using the following relationship (Mohsenin, 1970):

$$D_p = (LWT)^{1/3} \tag{1}$$

where L is the length, W is the width and T is the thickness (Fig. 1.).

According to Mohsenin (1970), the degree of sphericity (Φ) can be expressed as follows:

$$\Phi = \frac{(LWT)^{1/3}}{L} 100 \tag{2}$$

This equation was used to calculate the sphericity of fruits in the present investigation.

To obtain the mass, each fruit was weighed by a chemical balance reading to an accuracy of 0.001 g.

The true density of a peanut is defined as the ratio of the mass of a sample of a fruit to the solid volume occupied by the sample (Deshpande et al., 1993). The peanut volume and its true density were determined using the liquid displacement method. Toluene (C_7H_8) was used instead of water because it is absorbed by peanut to a lesser extent.

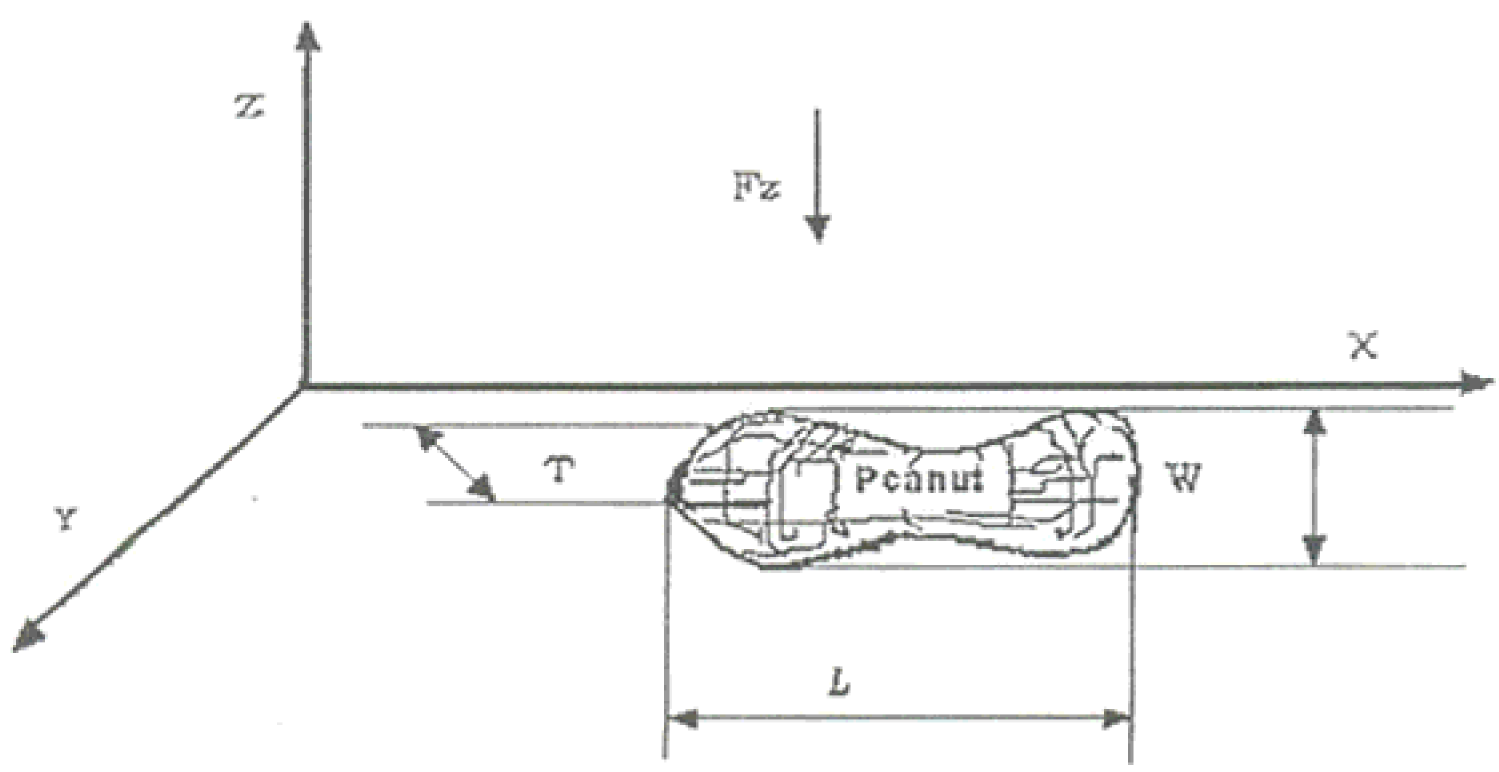

Fig. 1. Axis and three major perpendicular dimensions of peanut.

Also, its surface tension is low, so that it fills even shallow dips in a fruit and its dissolution power is low (Ögüt, 1998; Sitkei, 1986). The bulk density was determined with a weight per hectolitre tester which was calibrated in kg per hectolitre (Deshpande et al., 1993). The peanut were poured in the calibrated bucket up to its brim from a height of about 15 cm and excess peanut were removed by strike off stick. The peanut were not compacted in any way.

The porosity (ε) of bulk fruits were computed from the values of true density and bulk density using the relationship given by Mohsenin (1970) as follows:

$$\varepsilon = \frac{\rho_k - \rho_b}{\rho_k} 100 \quad (3)$$

where ρ_b is the bulk density and ρ_k is the true density.

The projected area of a peanut was measured by placing it under a thin transparent paper and using a planimeter equipped with a magnifying glass (Makanjuola, 1972).

The terminal velocities of peanut at different moisture content were measured using an air column. For each test, a small sample was dropped into the air stream from the top of the air column, air was blown to suspend the material in the air stream. The air velocity near the location of the fruit suspension was measured by an electronic anemometer having an accuracy of 0.1 m/s (Joshi, Das, & Mukherjee, 1993). Three replications for each fruit sample were made.

Biological material test device was used to determine the rupture strength of peanut and kernel. The device developed by Aydin and Ögüt (1992) has three main components which are stable up and motion bottom of platform, a driving unit and the data acquisition system. The fruit was placed on the stable up platform and pressed with motion probe (Ø2.2 mm). The rupture force of seed was measured by the force dynamometer and data acquisition system having a least count of 0.01 N.

The coefficients of frictions of peanut fruits having different moisture contents were measured using a friction device. The device developed by Tsang-Mui-Chung, Verma, and Wright (1984) and modified by Chung and Verma (1989) has three main components which are a stationary sample container with its support shaft, a driving unit with rotating disc and the data acquisition system. The samples were placed on the rotating surface and the torque necessary to restrain the sample was measured by the data acquisition system. This torque was used to determine the static and dynamic coefficients of friction using the following equation (Chung & Verma, 1989):

$$\mu = T_m/(wq) \quad (4)$$

where μ is the coefficient of friction, T_m is the measured torque, q is the length of the torque arm and w is the sample weight on the rotating surface. The maximum value of torque obtained as the disc started to rotate was used to calculate the static coefficient of friction and average value of the torque during the rotation of the disc was used to calculate the dynamic coefficient of friction.

3. Results and discussion

3.1. Dimensions and size distribution of peanut

Table 1 shows the size distribution of the peanut. The frequency distribution curves (Fig. 2) for the mean values of the dimensions shows a trend towards a normal distribution. About 80% of the fruits have a length ranging from 44.31 to 44.75 mm, about 80% width ranging from 16.64 to 16.71 mm, and about 80% thickness ranging from 15.68 to 15.74 mm. The values of mass and volume of a single peanut fruit were given in Table 1.

Table 2 shows the size distribution of the kernel. The frequency distribution curves (Fig. 3) for the mean values of the dimensions shows a trend towards a normal distribution. About 80% of the kernel have a length ranging from 20.92 to 20.97 mm, about 80% width ranging from 10.42 to 10.46 mm, and about 80% thickness ranging from 8.77 to 8.82 mm. In Tables 1 and 2, the values of mass and volume of a single peanut were higher than terebinth fruits (Aydin & Özcan, 2002). In Table 2, the average values of geometric

Table 1
Means and standard errors of the peanut sizes at 6% d.b.

Length (mm)	44.53 ± 0.17
Thickness (mm)	15.71 ± 0.023
Width (mm)	16.68 ± 0.027
Geometric mean diameter (mm)	23.0 ± 0.06
Sphericity (%)	51.6 ± 0.21
Mass (g)	2.16 ± 0.078
Volume (cm^3)	5.17 ± 0.11
Hull thickness (mm)	1.49 ± 0.0014

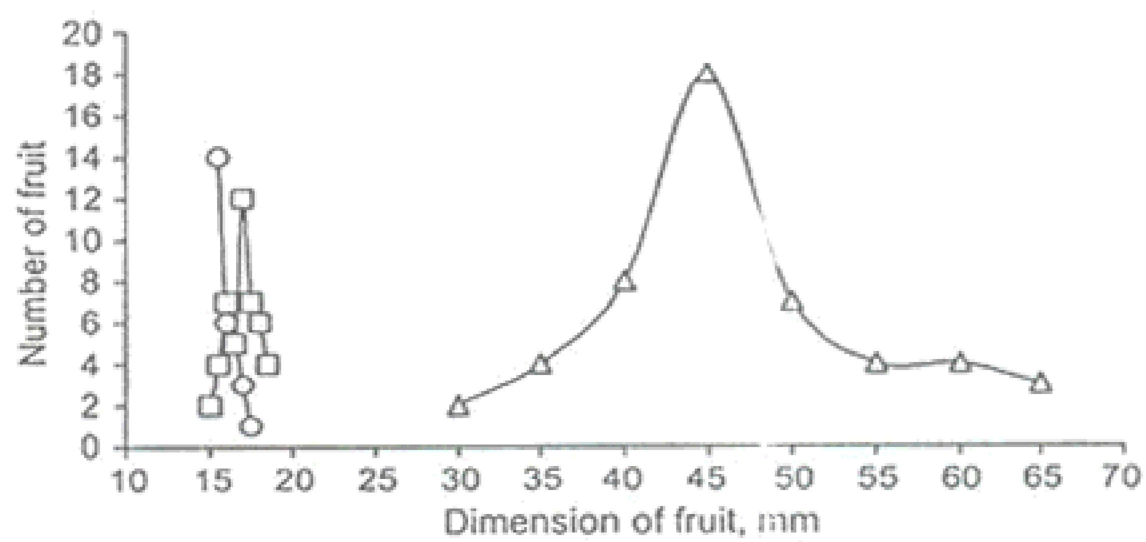

Fig. 2. Frequency distribution curves of peanut at 6% d.b. – (O), thickness; (□), width; (△), length.

Table 2
Means and standard errors of the kernel sizes at 4.85% d.b.

Length (mm)	20.95 ± 0.02
Thickness (mm)	8.8 ± 0.02
Width (mm)	10.44 ± 0.018
Geometric mean diameter (mm)	12.6 ± 0.06
Sphericity (%)	57.05 ± 0.17
Mass (g)	1.06 ± 0.018
Volume (cm^3)	1.14 ± 0.042

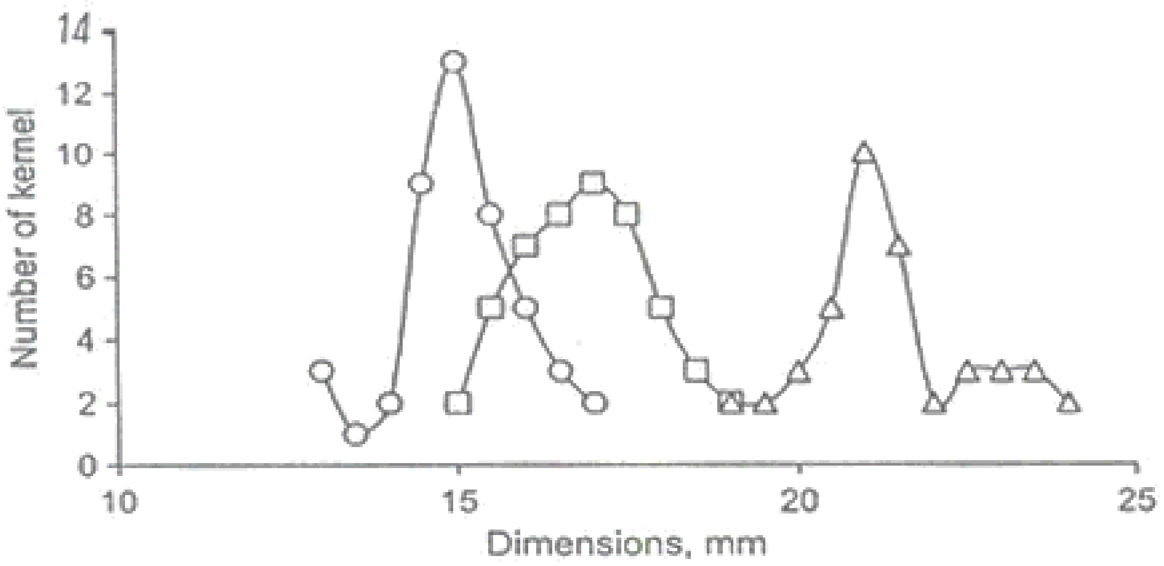

Fig. 3. Frequency distribution curves of peanut kernel at 4.85% d.b. – (○), thickness; (□), width; (△), length.

mean diameter and sphericity were calculated 6.99 mm and 77.8%, respectively. Nimkar and Chattopadhyay (2001) have reported the sphericity values of green gram as 81.5%, which is quite close to the results of this investigation.

3.2. Bulk density

The values of bulk density of peanut at different moisture levels varied from 243 to 184 kg/m^3 when the moisture content increased from 6% to 32% d.b. In addition, the bulk density of kernel at different moisture levels varied from 581 to 539 kg/m^3 (Fig. 4) and indicated a decrease in bulk density with an increase in moisture content. The decrease in bulk density with an increase in moisture content is mainly due to the increase in volume was higher than the corresponding increase in mass of the material. Furthermore the porosity increase with higher moisture content. The negative linear relationship of bulk density with moisture content was also observed by Aydin (2003), Gupta and Das (1997) and Wiswanathan et al. (1996) for neem nut, sunflower seed and almond nut, respectively. The statistical analysis of experimental data showed that relationship between bulk density and moisture content was significant ($p < 0.05$).

Bulk density (ρ_b) was found to have the following relationship with moisture content (M_c):

$$\text{for kernel:} \quad \rho_b = -2.08M_c + 589.84 \quad (R^2 = 0.99);$$

$$\text{for peanut:} \quad \rho_b = -2.27M_c + 255.96 \quad (R^2 = 0.99).$$

3.3. True density

The true density at peanut variety indicate the variety of peanut at different moisture levels varied from 424 to 545 kg/m^3. The effect of moisture content on true density of fruit showed an increase with moisture content. Effect of moisture content on true density of kernel showed an increase with moisture content, from 989 to 1088 kg/m^3 (Fig. 5). Balasubramanian (2001) also observed the linear increase in true density with increase moisture in the range 3.15–20.05% d.b. for cashew nut.

The relationship between true density (ρ_k) and the moisture (M_c) content was obtained as:

$$\text{for kernel:} \quad \rho_k = 4.91M_c + 968.18 \quad (R^2 = 0.99);$$

$$\text{for peanut:} \quad \rho_k = 4.64M_c + 399.09 \quad (R^2 = 0.99).$$

3.4. Porosity

The porosity of peanut was found to increase with increase in moisture content from 6% to 32% d.b. The porosity of kernel variety was found to slightly increase with increase in moisture content from 4.85% to 25% d.b. (Fig. 6). The form of the plot is similar to that of raw cashew nut as found by Balasubramanian (2001). Çarman (1996) reported a similar increase in porosity from 27.5% to 32.2% for lentil.

The relationship between moisture content (M_c) and porosity (ε) can be represented by the following equation:

$$\text{for kernel:} \quad \varepsilon = 0.54M_c + 38.01 \quad (R^2 = 0.98);$$

$$\text{for peanut:} \quad \varepsilon = 0.90M_c + 38.21 \quad (R^2 = 0.98).$$

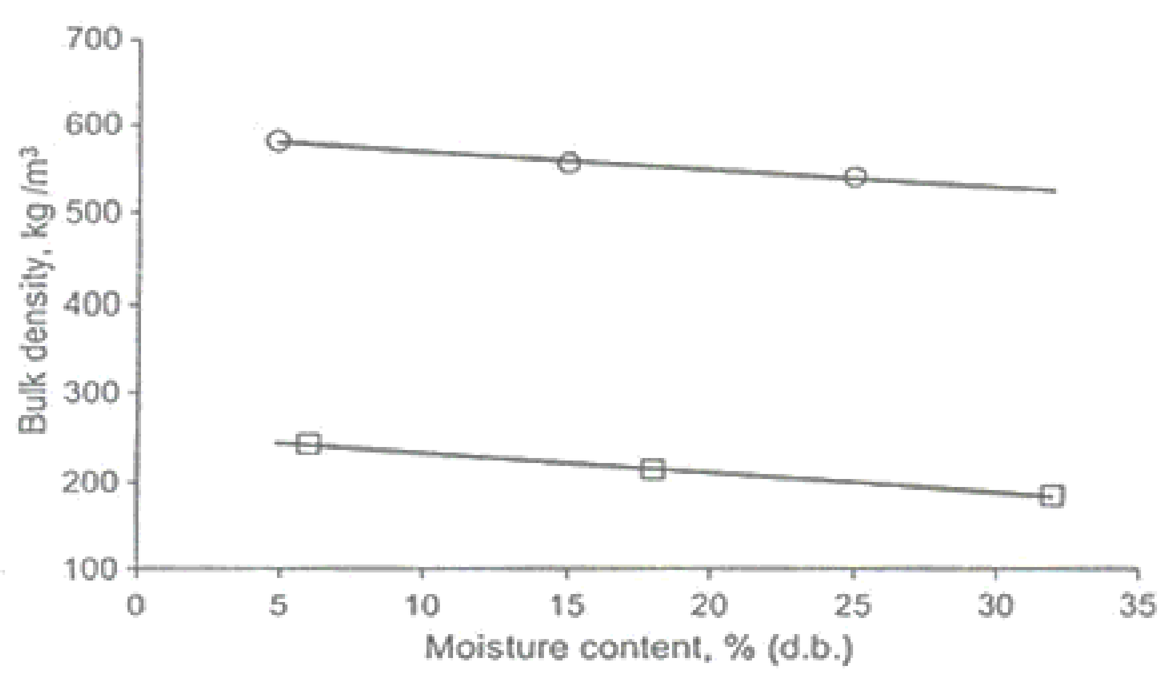

Fig. 4. Variation of bulk density of peanut with moisture content – (□), Peanut; (○), Kernel.

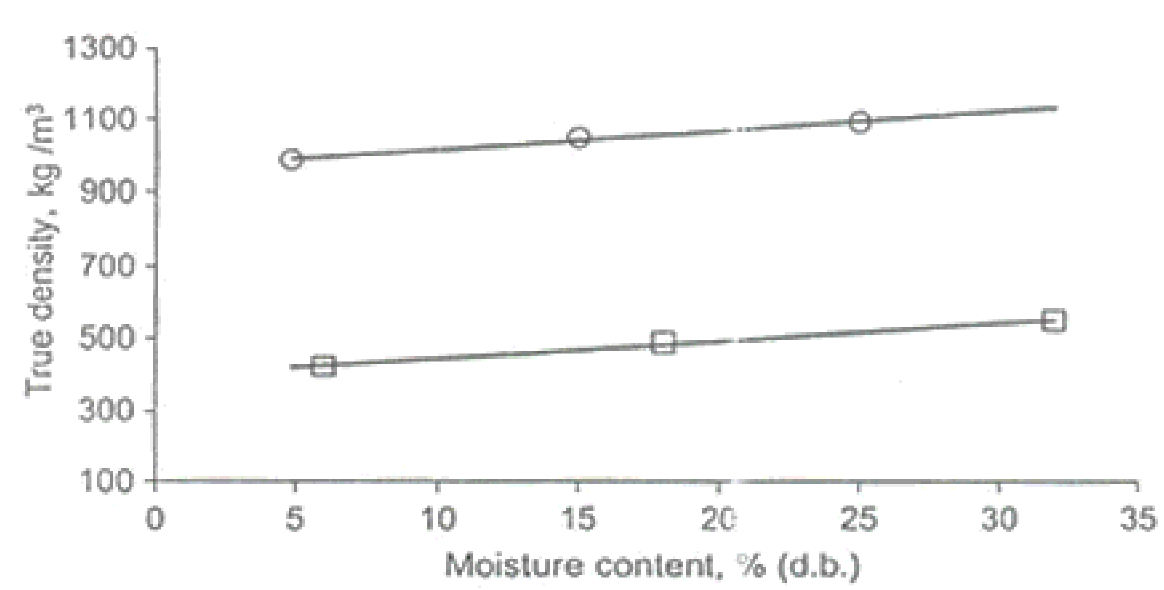

Fig. 5. Variation of true density of peanut with moisture content – (□), Peanut; (○), Kernel.

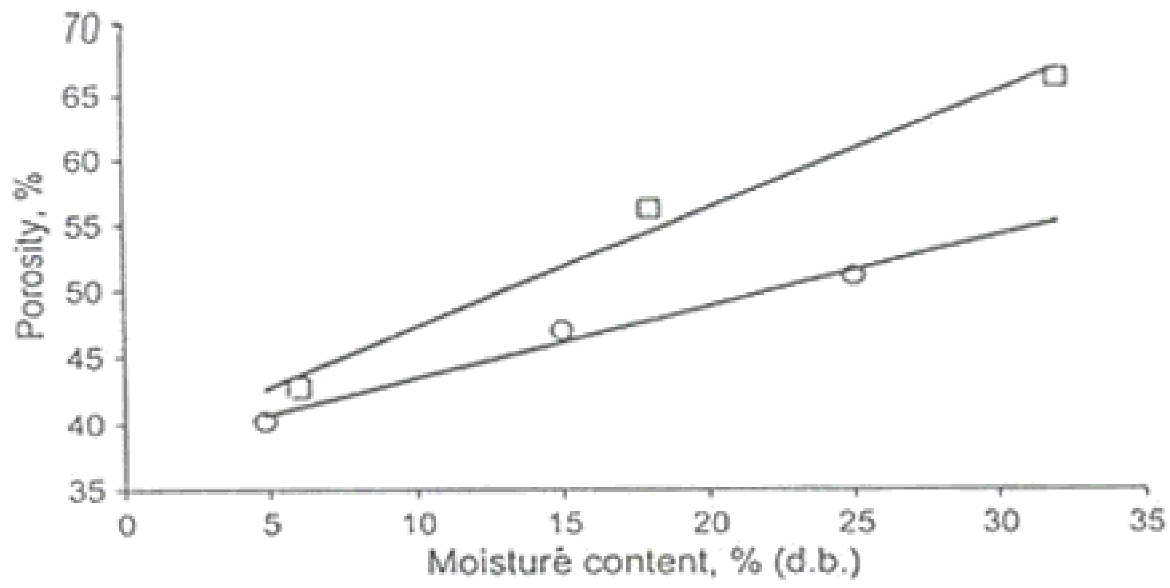

Fig. 6. Variation of porosity of peanut with moisture content – (□), Peanut; (○), Kernel.

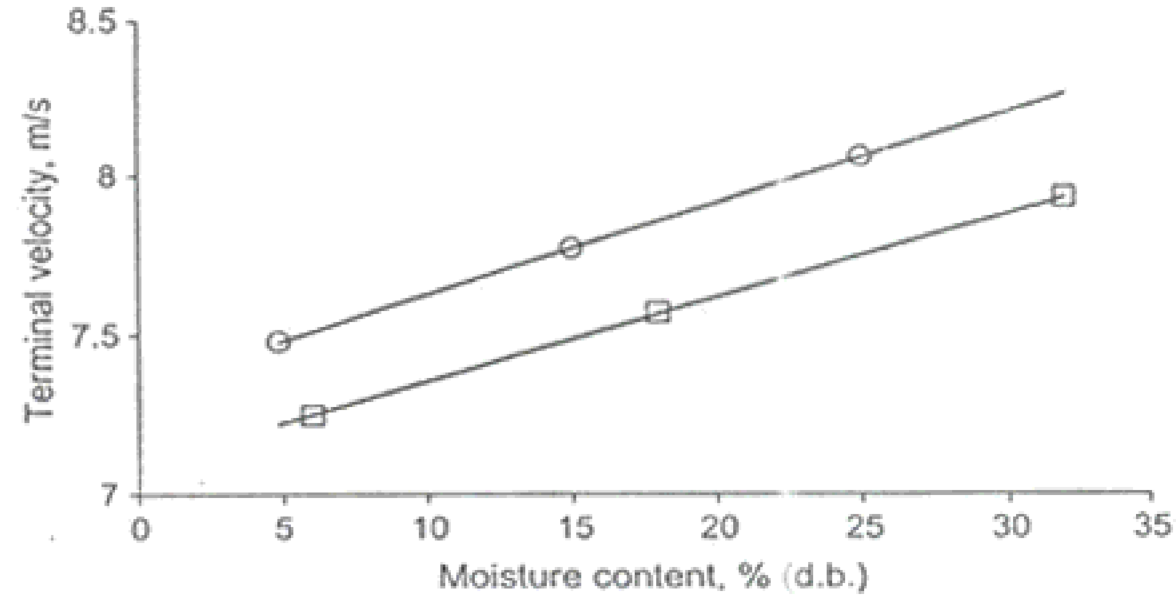

Fig. 8. Variation of terminal velocity of peanut with moisture content – (□), peanut; (○), Kernel.

3.5. *Projected area*

The projected area of peanut increased by 40.37%, while the moisture content of peanut increased from 6% to 32% d.b. Furthermore the projected area of kernel (Fig. 7) increased by about 36.60%, while the moisture content of kernel increased from 4.85% to 25% d.b. Similar trends were reported for many other seeds (Mohsenin, 1970; Sitkei, 1986). Deshpande et al. (1993) found that the surface area of soybean grain increased from 0.813 to 0.952 cm^2, when the moisture content was increased from 8.7% to 25% d.b.

The relationship between projected area (P_a) and moisture content (M_c) can be represented as:

$$\text{for kernel}: \quad P_a = 0.028M_c + 1.39 \quad (R^2 = 0.99);$$

$$\text{for peanut}: \quad P_a = 0.12M_c + 4.07 \quad (R^2 = 0.99).$$

3.6. *Terminal velocity*

The experimental results for the terminal velocity of the peanut and kernel at various moisture levels are plotted in Fig. 8. As moisture content increased, the terminal velocity was found to increase linearly. The results are similar to those reported by Kural and Çarman (1997), but the values were less than those for terebinth fruits (Aydin & Özcan, 2002). The increase in terminal velocity with increase in moisture content can be attributed to the increase in mass of an individual peanut per unit frontal area presented to the air stream.

The relationship between moisture content (M_c) and terminal velocity (V_t) can be represented by following equation:

$$\text{for fruit}: \quad V_t = 0.026M_c + 7.09 \quad (R^2 = 0.99);$$

$$\text{for kernel}: \quad V_t = 0.029M_c + 7.34 \quad (R^2 = 0.99).$$

3.7. *Dynamic coefficients of friction*

The dynamic coefficients of friction for peanut and kernel determined with respect to plywood and galvanised metal surfaces are presented in Figs. 9 and 10. It is observed that the dynamic coefficients of friction for peanut increased with increase in moisture content on all surfaces. In the moisture range from 6 to 32% d.b. dynamic coefficient of friction against plywood (0.43–0.73) for peanut was greater than the galvanised metal (0.30–0.50) dynamic coefficient of friction for kernel against plywood (0.29–0.63) was greater than galvanised metal (0.22–0.45). As the moisture content of the peanut increased, the dynamic coefficients increased significantly. Ögüt (1998)

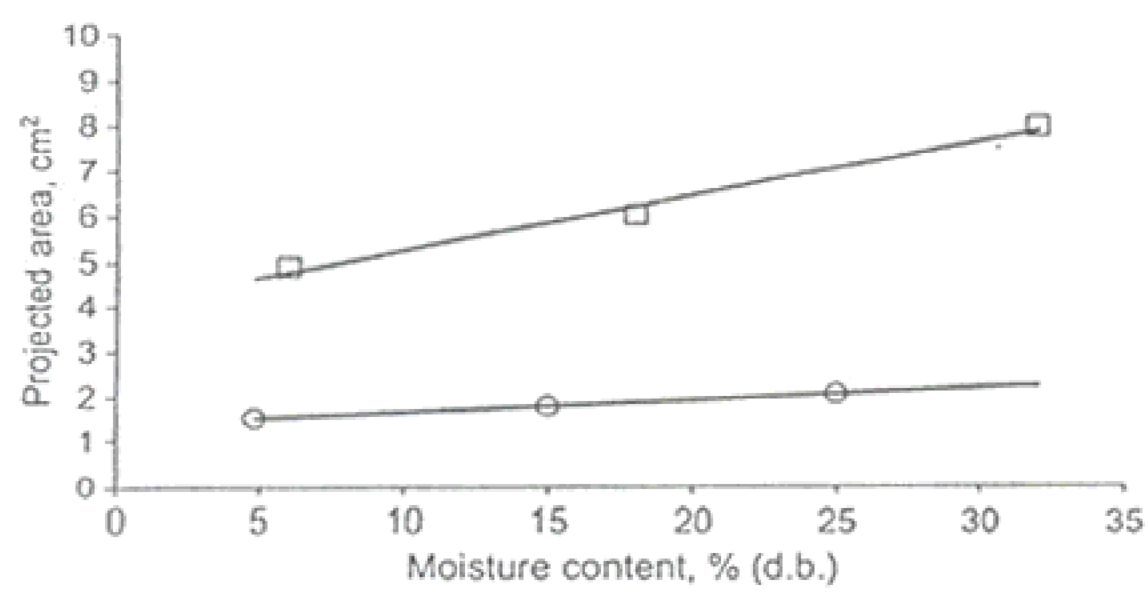

Fig. 7. Variation of projected area of peanut with moisture content – (□), Peanut; (○), Kernel.

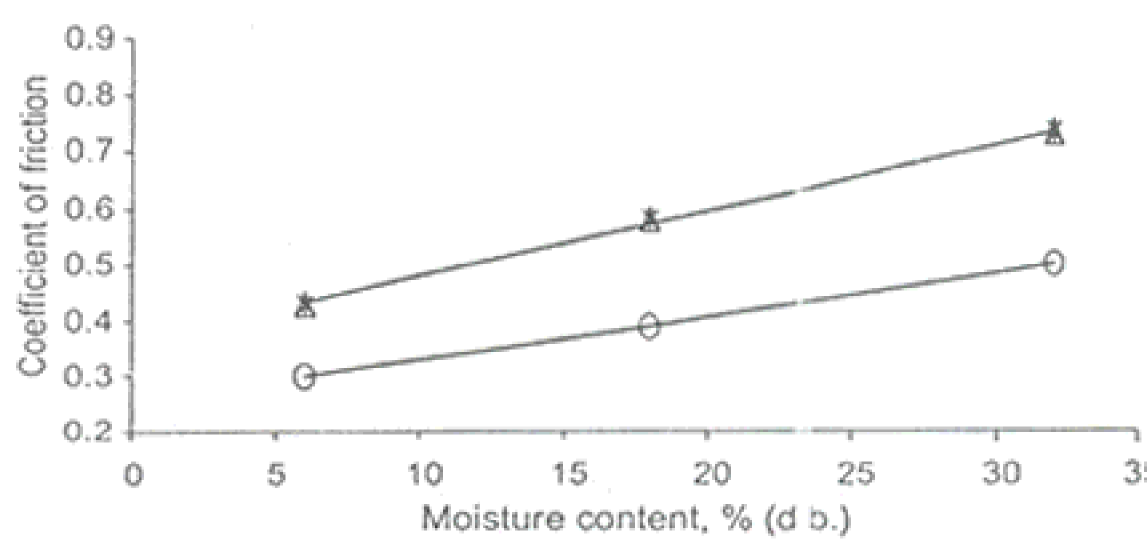

Fig. 9. Variation of coefficient of friction of peanut with moisture content – (△), plywood; (○), galvanised metal.

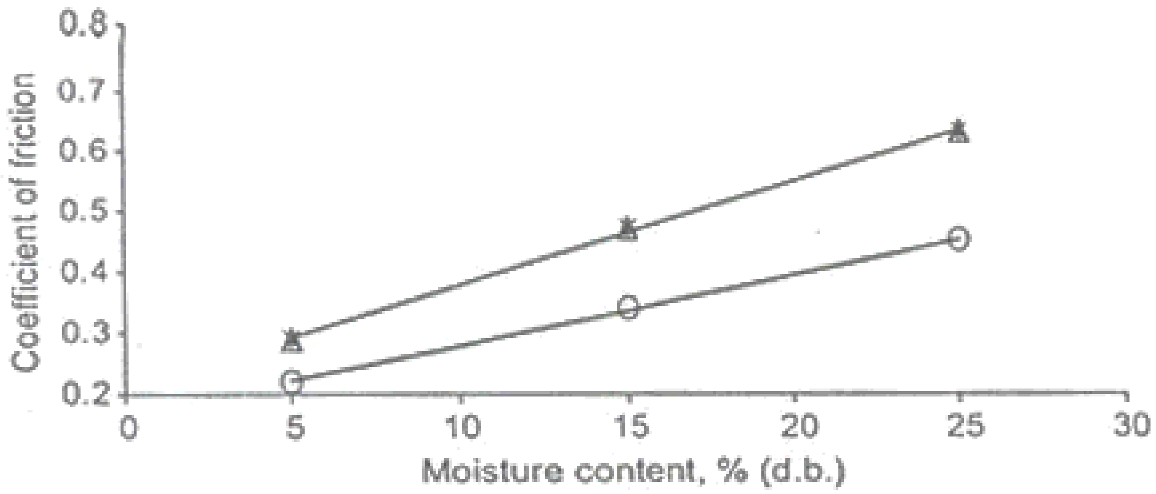

Fig. 10. Variation of coefficient of friction of kernel with moisture content – (Δ), plywood; (O), galvanised metal.

Table 3
Values for the coefficient A and B in the relationship between coefficient of friction and moisture content of peanut and kernel surfaces

	coefficient (A)	coefficient (B)	Coefficient of determination (R^2)
Peanut surfaces			
Plywood	0.0115	0.365	0.99
Galvanised metal	0.0077	0.253	0.99
Kernel surfaces			
Plywood	0.0170	0.208	0.99
Galvanised metal	0.0115	0.164	0.99

reported a similar result. It was observed that material surface had a more significant effect than the moisture content on the dynamic coefficient of friction.

The relationship between moisture content (M_c) and coefficients of friction (μ_d) can be represented by following equation and Table 3:

for varieties : $\mu_d = AM_c + B$

3.8. Rupture strength

The results of the rupture strength tests are presented Fig. 11. The results show that the rupture strength is highly dependent on moisture content for the range of moisture content investigated (4.85–32% d.b.). The highest force was obtained on loaded along the Fz. The small rupturing forces at higher moisture content might have resulted from the fact that the fruit tend to be very soft at high moisture content. The relationship between the rupture strengths and moisture content of the peanut major axis (Fig. 1) are presented in Fig. 11. The results are similar to those reported for various crops such as terebinth (Aydin & Özcan, 2002); and almond nut (Aydin, 2003).

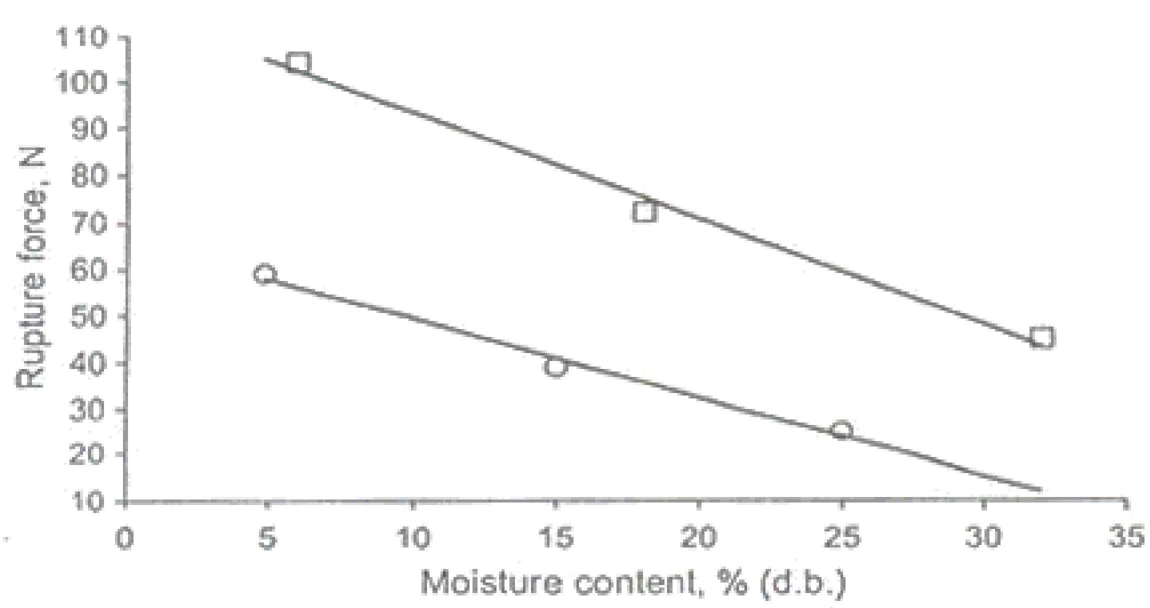

Fig. 11. Effect of moisture content on rupture strength of peanut – (□), peanut; (O), kernel.

The relationship between moisture content (M_c) and rupture strength (F_r) can be represented by following equation:

for fruit : $F_r = -2.26M_c + 115.85 \quad (R^2 = 0.99)$;

for kernel : $F_r = -1.69M_c + 66.24 \quad (R^2 = 0.99)$.

4. Conclusions

1. Peanut 6% m.c.d.b., the average length, thickness, width and geometric mean diameter were 44.53 mm, 15.71 mm, 16.68 mm and 23.0 mm, respectively. The average unit mass and volume were 2.61 g and 5.17 cm^3, respectively.
2. Peanut kernel 4.85% m.c.d.b., the average length, thickness, widely, and geometric mean diameter were 20.95 mm, 8.8 mm, 10.44 mm and 12.6 mm, respectively. The average unit mass and volume were 1.06 g and 1.14 cm^3, respectively.
3. The bulk density of peanut and kernel at different moisture levels varied from 243 to 184 kg/m^3 and from 581 to 539 kg/m^3, respectively.
4. The true density of peanut and kernel at different moisture levels varied from 424 to 545 kg/m^3; and from 989 to 1088 kg/m^3, respectively.
5. The terminal velocity increased linearly from 7.25 to 8.06 m/s as the moisture content increased from 4.85% to 32% d.b.
6. The rupture strength was highly dependent on moisture content. The highest rupture strength was obtained as 13.22 N/mm^2 while loading along F_z-axis having moisture content of 11.3% d.b. Generally the peanut become soft at high moisture content hence they required less force to rupture.
7. The dynamic coefficients of friction of peanut increased with moisture content.

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