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Some Physical Properties of Pumpkin (*Cucurbita pepo* L.) and Watermelon (*Citrullus lanatus* L.) Seeds

Ebubekir ALTUNTAŞ[1]

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Abstract: Some physical properties of pumpkin (*Cucurbita pepo* L.) and watermelon (*Citrullus lanatus* L.) seeds were determined at a moisture content of 9.87% and 2.87% (dry basis), respectively. The mean values of length, width, thickness and geometric mean diameter were 19.92, 11.30, 3.22, 9.71 mm for pumpkin seeds, and 13.28, 8.00, 2.64, 6.52 mm for watermelon seeds, respectively. The mean 1000 seed mass, sphericity, angle of repose, bulk and true densities, single seed volume, surface area, porosity values were obtained as 261.2 g, 60.55%, 23.9°, 321.3 kg/m^3, 784.3 kg/m^3, 0.11 cm^3, 2.54 cm^2 and 58.9%, respecitvely for pumpkin seed; and 14.62 g, 49.2%, 19.1°, 412.2 kg/m^3, 1543.3 kg/m^3, 0.03 cm^3, 0.48 cm^2 and 47.45%, respectively for watermelon seed. The mean values of dynamic coefficient of friction against galvanized steel, chipboard, mild steel, plywood and rubber surfaces were 0.29, 0.24, 0.32, 0.36 and 0.61 for pumpkin seed, and 0.21, 0.45, 0.41, 0.57 and 0.94 for watermelon seed; while the values of static coefficient of friction were 0.37, 0.38, 0.38, 0.43 and 0.74 for pumpkin seed and 0.27, 0.54, 0.48, 0.70 and 1.11 for watermelon seed, respectively. The maximum static and dynamic coefficients of friction was found for rubber surface.

Key Words: Pumpkin (***Cucurbita pepo* L.)** seed, watermelon (*Citrullus lanatus* L.)seed, physical properties

Balkabağı (*Cucurbita pepo* L.) ve Karpuz (*Citrullus lanatus* L.) Tohumlarının Bazı Fiziksel Özellikleri

Öz: Kabak (*Cucurbita pepo* L.) ve karpuz (*Citrullus lanatus* L.) tohumlarının sırasıyla %9,87 ve %2,87 k.b.(% kuru baz) nem içeriklerindeki bazı fiziksel özellikleri belirlenmiştir. Ortalama uzunluk, genişlik, kalınlık ve geometrik ortalama çap değerleri kabak tohumu için sırasıyla 19,92; 11,30; 3,22; 9,71 mm ve karpuz tohumu için 13,28; 8,00; 2,64; 6,52 mm olarak belirlenmiştir. Ortalama 1000 tane ağırlığı, küresellik, doğal yığılma açısı, hacim ağırlığı, kütlesel yoğunluk, tane hacmi, yüzey alanı, porozite değerleri sırasıyla kabak tohumu için 261,2 g; 60,55%; 23,9°; 321,3 kg/m^3; 784,3 kg/m^3; 0,11 cm^3; 2,54 cm^2 ve 58,9% olarak, karpuz tohumu için 14,62 g; 49,2%; 19,1°; 412,2 kg/m^3; 1543,3 kg/m^3; 0,030 cm^3; 0,48 cm^2 and 47,45% olarak belirlenmiştir. Ortalama dinamik sürtünme katsayıları galvaniz sac, sunta, sac, kontrplak ve lastik yüzeylere göre kabak tohumu için sırasıyla 0,29; 0,24; 0,32; 0,36 ve 0,61, karpuz tohumu için 0,21; 0,45; 0,41; 0,57 and 0,94 olarak bulunurken, statik sürtünme katsayısı değerleri ise aynı sürtünme yüzeyleri için sırasıyla, kabak tohumunde, 0,37; 0,38; 0,38; 0,43 and 0,74 ve karpuz tohumunde ise, 0,27; 0,54; 0,48; 0,70 and 1,11 olarak belirlenmiştir. Maksimum statik ve dinamik sürtünme katsayıları lastik yüzeyde bulunmuştur.

Anahtar Kelimeler: Kabak (*Cucurbita pepo* L.) tohumu ve karpuz (*Citrullus lanatus* L.) tohumu, fiziksel özellikler

Introduction

Pumpkin (Cucurbita pepo L.) is a familiar fruit; it is a herbaceous running plant belonging to the melon family. The pumpkin fruit grows annually on vines that may reach up to 7.92 m in length. The pumpkin belongs to the plant genus Cucurbita, comprising melons and squash like fruits. The seeds of many species in this plant genus are regarded as being very potent and effective teniafuges (Herbs_pumpkin, 2007). The cultivation of pumpkins is carried out worldwide due to its widespread use in many cuisines; however, pumpkin cultivation is greater in scale in the temperate regions of the world. Temperate North America is where the pumpkin originated. The use of the pumpkin seeds in herbal medicine is mainly as a natural and safe de-worming agent, the seeds are able to rid the body of all intestinal helminthes and parasites when used properly (Herbs_pumpkin, 2007).

[1] Gaziosmanpasa University, Faculty of Agriculture, Department of Agricultural Machinery- Tokat/Turkey

Pumpkin seeds contain 30% unsaturated fixed oil (which includes linoleic and oleic fatty acids). The seeds also contain cucurbitacins, vitamins, and minerals, notably zinc. Pumpkins are usually harvested late in the summer, at these time, seeds are removed from the pulp inside the pumpkin and stored for later use, while the pulp itself is used for food. Pumpkin is a vegetable that is widely grown in Turkey. The seed is also regarded as an important source of protein. According to the United Nations Food and Agriculture Organization, there are an estimated 22.000 hectares of pumpkins in Turkey, producing 368.000 tons and is 1.48% of total fruits bearing vegetable production (FAO 2005).

Watermelon (*Citrullus lanatus* L.), the fruit that is really a vegetable. Watermelon can be traced back to Africa and is part of the cucumber and squash family. Watermelon contains high concentrations of lycopene, an antioxidant that may help reduce the risks of cancer and other diseases. Watermelon is fat free, nutritionally low in calories and considered an ideal diet food, and is high in energy, making it a great energy boost. Watermelon, today's varieties are larger, the flesh sweeter, the seeds smaller and the rind thinner. It is perhaps the most refreshing, thirst quenching fruit of all. Watermelon consists of 92% water and 8% sugar. There are more than 50 varieties of watermelon. Most have red flesh, but there are orange and yellow-fleshed varieties (Artwatermelon 2007). The seeds of the watermelon are employed, to a considerable extent, as a domestic remedy in strangury and other affections of the urinary passages. Some researcher found in watermelon seeds a fixed oil very similar to that which is found in pumpkin seeds (Watermelon 2007).

Nomenclature			
D	the diameter of cone, cm.	S	surface area, %
D_g	geometric mean diameter, mm	T	thickness, mm
H	height of the cone, cm	V	volume of seed, cm^3
F	measured friction force, N	W	width, mm
L	length, mm	ρ_b	bulk density, kg/m^3
M	mass of seed, g	ρ_t	true density, kg/m^3
m_{1000}	thousand seed mass, g	μ	coefficient of friction
N_f	normal force, N	ϕ	sphericity, %
p	porosity, %	Θ	angle of repose, °

Watermelon seed oil is also beneficial for human healty. The presence of omega 6 and omega 9 essential fatty acids helps the skin immensely. This oil has a very good absorption level which readily penetrates the skin and dissolves the sebum buildup (Hopkins 2007). In the USA (Texas, Michigan Delaware, Indiana, Iowa, Colorado and Florida) are big producers and shippers, but Mexico, France, Italy, Spain, Portugal, Greece, Turkey and Croatia are also known to grow and export considerable amounts. There are an estimated 137.000 hectares of watermelons in Turkey, producing 3.970.000 tons and is 4.17% of total fruits bearing vegetable production (FAO 2005).

The physical properties of pumpkin and watermelon seeds are to be known; for design and improve of relevant machines and facilities for harvesting, storing, handling, granding and processing. The size and shape are important in designing of seperating, harvesting, sizing and granding machines. Bulk density and porosity affect the structural loads at silo. The angle of repose is important in designing of storage and transporting structures. The coefficient of friction of the pumpkin and watermelon seeds against the various surface is also necessary in designing of conveying, transporting and storing structures. In recent years, physical properties have been studied for various crops such as cotton seed (Ozarslan 2002), millet (Baryeh 2002), hemp seed (Sacilik et al. 2003), quiona seed (Vilche et al. 2003) lentil seed (Amin et al. 2004), sesame seed (Tunde-Akindute and Akindute 2004), Hungarian and common vetch seeds (Taser et al. 2005), fenugreek seed (Altuntas et al. 2005), gilaburu seed (Sönmez et al. 2007). However, studies conducted on the pumpkin and watermelon seeds have not been adequately together and comparatively studied.

The objective of this study was to investigate some physical properties of size dimension, sphericity, thousand seed mass, bulk density, angle of repose, volume, true density, porosity, surface area and the static and dynamic coefficients of friction on various surfaces for pumpkin and watermelon seeds.

Materials and Methods

Pumpkin (*Cucurbita pepo* L.) and watermelon (*Citrullus lanatus* L.) seeds used in the study were obtained from a special market in Tokat, Turkey. The samples were cleaned manually to remove all foreign matter, dust, dirt, broken and immature seeds. The moisture content of the samples was determined by oven drying at 105 ± 1 °C for 24 h (Suthar and Das, 1996). Each of the samples was replicated three times and the mean moisture content of pumpkin and watermelon seed was found as 9.87 and 2.87% d.b. (dry basis), respectively.

To determine the seed size; one hundred seeds were randomly selected and length, width and thickness were measured using a dial-micrometer to an accuracy of 0.01 mm. The geometric mean diameter D_g and sphericity Φ of pumpkin and watermelon seeds was calculated by using the following relationships (Mohsenin 1970):

$$D_g = (LWT)^{1/3} \quad (1)$$

$$\Phi = \left[\frac{LWT^{1/3}}{L}\right] \times 100 \quad (2)$$

where L is the length, W is the width and T is the thickness in mm.

Thousand seed masses were measured by an electronic balance with 0.001g accuracy. Hundered randomly selected seeds from the bulk were averaged to evaluate thosand seed mass. The true density of a seed is defined as the ratio of the mass of a sample of a seed to the solid volume occupied by the sample (Deshpande et al. 1993). The seed volume and its kernel density were determined using the liquid displacement method. Toluen (C_7H_8) was used rather than water because it is absorbed by seeds to a lesser extent. Toluen surface tension is low, so that it fills even shallow dips in a seed and its dissolution power is low (Sitkei 1976, Mohsenin 1970). The bulk density is the ratio of the mass of to total volume of a sample and it was determined with a weight per hectolitre tester which was calibrated in kg/m^3 (Deshpande et al. 1993, Suthar and Das 1996). The porosity (p) was determined by the following equation:

$$p = \left[1 - \frac{\rho_b}{\rho_t}\right] \times 100 \quad (3)$$

where ρ_b and ρ_t the bulk density and the true density, respectively (Mohsenin 1970).

The surface area of forage plants seeds namely pumpkin and watermelon was found by analogy with a sphere of same geometric mean diameter, using experisson cited by Olajide and Ade-Omowaye (1999), Sacilik et al. (2003):

$$S = \pi D_g^{\ 2} \quad (4)$$

where S is the surface area in mm^2 and D_g is the geometric mean diameter in mm.

In order to determine the angle of repose; topless and bottomless cylinder with 300 mm diameter and 500 mm height was used. The cylinder was placed at the center of a raised circular plate and was filled with seed. The cylinder was raised slowly until it formed a cone on a circular plate. The angle of repose (θ) was calculated from the measurement of the height of the cone and the diameter of cone (Viswanathan et al. 1996, Kaleemullah and Gunasekar 2002).

$$\Theta = \tan^{-1} 2(H/D) \quad (5)$$

where: H is the height of the cone in cm and D is the diameter of cone in cm.

The coefficient of friction of pumpkin and watermelon seeds was measured by a friction device The measuring device of friction force is formed by a metal box, a friction surface, and an electronic unit, which covers the mechanical force unit, electronic variator, loadcell, electronic ADC (Analog digital converter) card, and PC (Personel computer) (Kara et al. 1997, Kasap and Altuntas 2006). Friction force were measured by the loadcell, converted by the ADC card, and data were recorded in a computer. A shematic of the measuring device of friction force is shown in Fig. 1. The static and dynamic coefficients of friction were calculated using the following equation:

$$\mu = \left[\frac{F}{N_f}\right] \quad (6)$$

where, μ is the coefficients of friction, F is the measured friction in N, and N_f is the normal force in N.

The maximum value of friction force was obtained when box started moving, and this was used to calculate the static coefficients of friction. While the box continued to slide over the friction surface at 0.02 m/s velocity, the dynamic coefficients of friction were measured. The average value of coefficient of friction was used to calculate the dynamic coefficients of friction. The experiment was conducted on pumpkin and watermelon seeds using friction surfaces of galvanized metal, chipboard, mild steel, plywood and rubber For each experiment, the sample box was emptied and refilled with a different sample at the same moisture content (Sacilik et al. 2003).

Results and Discussion

The length, width and thickness of pumpkin seeds ranged from 15.74 to 24.44 mm, 9.04 to 14.09 and 2.04 to 4.54 mm, respectively (Table 1). About 83% of the pumpkin seeds have a length ranging

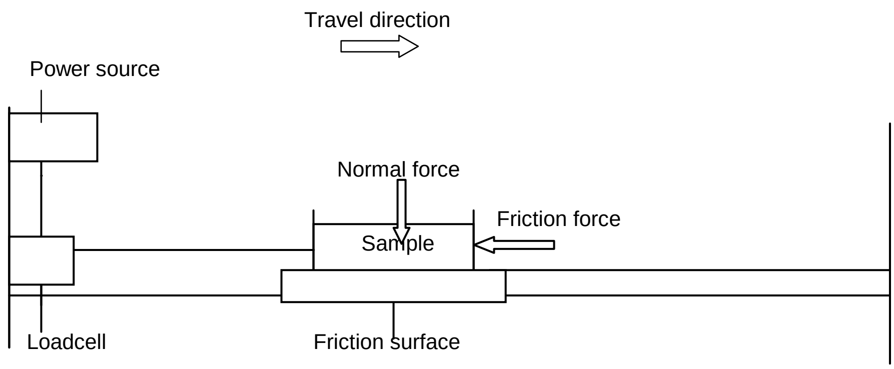

Figure 1. A shematic of the measuring device of friction force.

Table 1. Some physical properties of pumpkin seeds at a moisture content of 9.87% d.b.

Physical properties	Mean	Maximum	Minimum	SD
Length, L (mm)	19.92	24.44	15.74	1.83
Width, W (mm)	11.30	14.09	9.04	1.06
Thickness, T (mm)	3.22	4.54	2.04	0.47
Geometric mean diameter, D_g (mm)	9.71	10.54	7.66	3.84
Sphericity, Φ (%)	60.55	71.17	54.36	6.52
1000 seed mass, m_{1000} (g)	261.17	268.10	251.10	0.89
Bulk density, ρ_b (kg/m^3)	321.34	325.43	317.61	3.00
True density, ρ_t (kg/m^3)	784.326	814.15	729.18	47.8
Angle of repose, θ (°)	23.88	28.36	20.54	2.47
Porosity, p (%)	58.92	60.53	55.93	2.59
Surface area, S (cm^2)	2.54	3.71	1.52	0.43
Unit seed mass, m (g)	0.21	0.29	0.10	0.04
Single seed volume, V (cm^3)	0.111	0.119	0.107	0.007
Coefficient of friction on				
Plywood	0.36	0.43	0.29	0.03
Galvanize steel	0.29	0.37	0.22	0.04
Mild steel	0.32	0.38	0.24	0.03
Chipboard	0.24	0.38	0.18	0.04
Rubber	0.61	0.74	0.33	0.08

from 17.63 to 22.38 mm, about 78% a width ranging from 10.19 to 12.81 mm, about 86% a thickness ranging from 2.59 to 3.91 mm and about 69% a seeds mass ranging from 0.260 to 0.269 g at 9,87% moisture content on dry basis (Fig. 2).

For a comparision between length, width, thickness, unit seed mass, geometric mean diameter, surface area and sphericity of pumpkin seed the relationships between has been established. Correlation coefficients for these relations are given in Table 2. The relations between L/W, L/T, L/Dg, L/S and L/ϕ have been found to be statistically significant. L/M has not been found to be statistically significant.

The length, width and thickness of watermelon seeds ranged from 11.83 to 14.93 mm, 7.16 to 9.40 mm, 2.05 to 3.75 mm, respectively (Table 3). About 77% of the watermelon seeds have a length ranging from 12.20 to 13.78 mm, about 70% a width ranging from 7.36 to 8.84 mm, about 72% a thickness ranging from 2.17 to 3.11 mm and about 69% a seeds mass ranging from 0.109 to 0.197 g at 9.87% moisture content on dry basis (Fig. 3).

Correlation coefficients for L/W, L/T, L/M, L/Dg, L/S and L/ϕ relations of watermelon seeds are given Table 4. The relations between L/W, L/Dg, L/S and L/ϕ and have been found to be statistically significant. L/T and L/M have not been found to be statistically significant. The geometric diameter was 9.71 mm and 6.52 mm for pumpkin and watermelon seeds, respectively.

The sphericity values of pumpkin and water-melon seeds were found 54.36 to 71.17% and 44.10 to 55.64%, respectively. The mean 1000 seed mass of pumpkin and watermelon seed were found to be

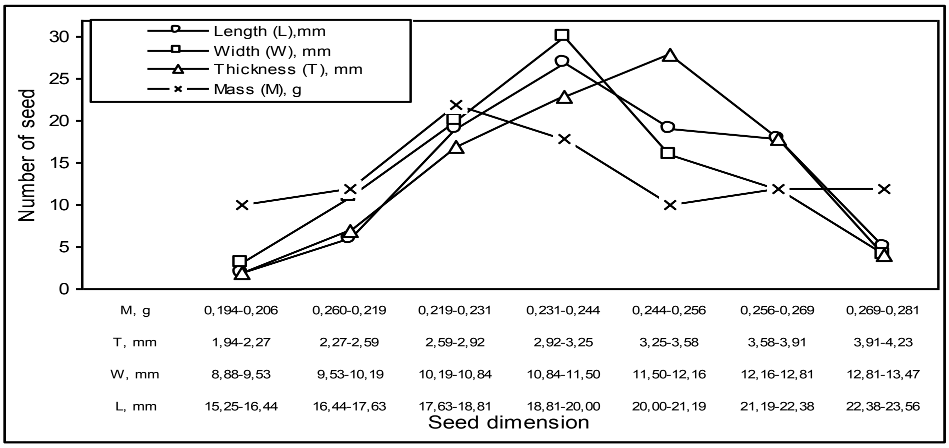

Figure 2. Frequency distribution curves of pumpkin seed length, width, thickness and unit mass of the seed at a moisture content of 9.87% d.b.

Table 2. The correlation coefficients of pumpkin seeds at a moisture content 9.87% d.b.

Particulars	Mean	Minimum	Maximum	Standard deviation	Degrees of freedom	Correlation coefficient (R)
L/W	1.78	2.13	1.48	0.14	98	0.65**
L/T	6.29	8.97	3.47	0.96	98	0.25**
L/M	97.3	198.2	62.7	22.1	98	0.09^{ns}
L/Dg	1.64	1.84	1.41	0.08	98	0.76**
L/S	5.64	7.01	4.56	0.54	98	0.76**
*L/*Φ	0.25	0.32	0.17	0.03	98	-0.40**

** Significant at 1% level, ^{ns} Non significant.

Table 3. Some physical properties of watermelon seeds at a moisture content of 2.87% d.b.

Physical properties	Mean	Maximum	Minimum	SD
Length, L (mm)	13.28	14.93	11.83	0.65
Width, W (mm)	8.00	9.40	7.16	0.47
Thickness, T (mm)	2.64	3.75	2.05	0.28
Geometric mean diameter, D_g (mm)	6.52	7.32	5.96	0.32
Sphericity, Φ (%)	49.17	55.64	44.10	2.26
1000 seed mass, m_{1000} (g)	14.62	14.02	15.12	0.56
Bulk density, ρ_b (kg/m^3)	412.15	424.09	406.21	0.01
True density, ρ_t (kg/m^3)	1543.3	1762.4	1324.0	219.2
Angle of repose, θ (°)	19.08	20.51	17.25	1.21
Porosity, p (%)	47.45	54.61	39.58	7.54
Surface area, S (cm^2)	1.34	1.68	1.12	0.13
Unit seed mass, M (g)	0.14	0.24	0.05	0.02
Single seed volume, V (cm^3)	0.030	0.034	0.026	0.004
Coefficient of friction on				
Plywood	0.57	0.70	0.45	0.05
Galvanize steel	0.21	0.27	0.15	0.03
Mild steel	0.41	0.48	0.26	0.05
Chipboard	0.45	0.54	0.35	0.04
Rubber	0.94	1.11	0.83	0.08

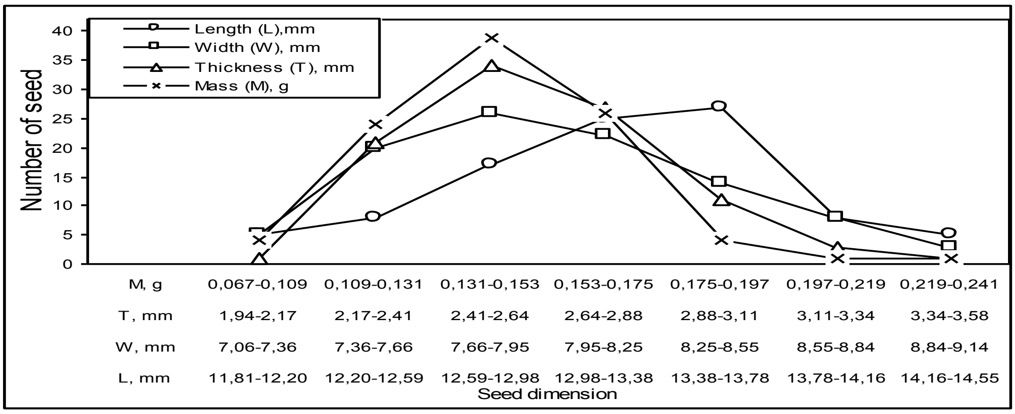

Figure 3. Frequency distribution curves of watermelon seed length, width, thickness and unit mass of the seed at a moisture content 2.87% d.b.

Table 4. The correlation coefficients of watermelon seeds at 2.87% moisture content (d.b.)

Particulars	Mean	Minimum	Maximum	Standard deviation	Degrees of freedom	Correlation coefficient (R)
L/W	1.66	1.91	1.41	0.10	98	0.33**
L/T	5.09	6.34	3.48	0.53	98	0.12**
L/M	95.9	275.4	57.2	27.0	98	0.11^{ns}
L/Dg	2.04	2.27	1.80	0.09	98	0.55**
L/S	9.99	11.95	8.01	0.79	98	0.55**
L/Φ	0.27	0.33	0.22	0.02	98	-0.47**

** Significant at 1% level, ^{ns} Non significant.

261.17 and 14.62 g, respectively. The bulk density were changed between 317.61 to 325.43 kg/m^3 and 406.21 to 424.09 kg/m^3 for pumpkin and watermelon seeds, respectively. The true density were ranged from 729.18 to 814.15 kg/m^3 and 1324.0 to 1762.4 kg/m^3 for pumpkin and watermelon seeds, respectively (Table 1 and 3). The mean angles of repose of pumpkin and watermelon seeds were 23.88 and 19.08°, respectively. The mean angle of repose of pumpkin is considerably lower than that reported for sesame seed as 32° by Tunde-Akindute and Akindute (2004), and mean angle of repose of watermelon is similar for locust bean seed as 20.32° by Ogunjimi et al. (2002). The single volume of pumpkin and watermelon seed were 0.111 and 0.030 cm^3. The porosity were ranged from 55.93 to 60.53% and 39.58 to 54.61% for pumpkin and watermelon seeds, respectively. The surface area were changed from 1.52 to 3.71 cm^2 and 1.12 to 1.68 cm^2 for pumpkin and watermelon seeds, respectively.

The values of dynamic and static coefficients of friction against the various test surfaces for plywood, mild steel and galvanized metal, chipboard and rubber for punpkin and watermelon seeds were given in Table 1 and 3. The mean values of coefficient of dynamic friction against galvanized steel, chipboard, mild steel, plywood and rubber surfaces were 0.29, 0.24, 0.32, 0.36 and 0.61 for pumpkin seed, and 0.21, 0.45, 0.41, 0.57 and 0.94 for watermelon seed; while the values of coefficient of static friction were 0.37, 0.38, 0.38, 0.43 and 0.74 for pumpkin seed and 0.27, 0.54, 0.48, 0.70 and 1.11 for watermelon seed, respectively.

From these results, static coefficients of friction is higher than dynamic coefficients of friction. Both the static and dynamic coefficient of friction were least for pumpkin and watermelon seeds againts galvanized metal -chipboard and highest for plywood and rubber. Similar results were found by other researchers (Taser et al. 2005 for Hungarian and common vetch; Ozgoz et al. 2005 for yarma and bulgur; Altuntas and Karadag, 2006 for sainfoin, grasspea and bitter vetch seeds; Altuntas and Demirtola 2007 for kidney bean, dry pea and black-eyed pea seeds.).

Conclusions

The following conclusions are drawn from the investigation on physical and mechanical properties of some physical properties of pumpkin (*Cucurbita pepo* L.) and watermelon (*Citrullus lanatus* L.) seeds at moisture content of 9.87 and 2.87% d.b., respectively.

1. The mean values of lenght, width, thickness and geometric mean diameter were 19.92, 11.30, 3.22, 9.71 mm for pumpkin seed; while The mean values of lenght, width, thickness and geometric mean diameter were 13.28, 8.00, 2.64, 6.52 mm, for watermelon seed, respectively.

2. The mean 1000 seed mass, sphericity, angle of repose, were obtained as 261.2 g, 60.55% and 23.9° for pumpkin seed; and 14.62 g, 49.2% and 19.1° for watermelon seed, respectively.

3. The bulk and true density, single seed volume, surface area, porosity values were obtained as 321.3 kg/m^3, 784.3 kg/m^3, 0.11 cm^3, 2.54 cm^2 and 58.9% for pumpkin seed, while the bulk and true density, single seed volume, surface area, porosity values were 412.2 kg/m^3, 1543.3 kg/m^3, 0.030 cm^3, 0.48 cm^2 and 47.45%, respectively.

4. The mean values of coefficient of dynamic friction against galvanized steel, chipboard, mild steel, plywood and rubber surfaces were 0.29, 0.24, 0.32, 0.36 and 0.61 for pumpkin seed, and 0.21, 0.45, 0.41, 0.57 and 0.94 for watermelon seed; while the values of coefficient of static friction were 0.37, 0.38, 0.38, 0.43 and 0.74 for pumpkin seed and 0.27, 0.54, 0.48, 0.70 and 1.11 for watermelon seed, respectively.

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Communication address:
Ebubekir ALTUNTAŞ
Gaziosmanpasa University, Faculty of Agriculture,
Agricultural Machinery- Tokat/Turkey.
Phone: 0 356 252 16 16
E-mail:ealtuntas@gop. edu.tr