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Some Engineering Characteristics of Shelled and Unshelled Confectionery Sunflower Seeds Belonging to the Different Genotypes

Hamide Ersoy[1] Ebubekir Altuntaş[1]* Esra Nur Gul[1]
[1]Department of Biosystems Engineering, Faculty of Agriculture, University of Tokat Gaziosmanpasa, Tokat
***Corresponding author's email:** ebubekir.altuntas@gop.edu.tr

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Abstract: In this study, the engineering characteristics of the shelled and unshelled sunflower seeds of the AYBAK-2013-12-DAÇ13099, AYBAK-2013-17-DAÇ130104, and 09 TRÇ 004 genotypes were determined. Moisture contents of the sunflower seeds were 7.22, 7.08, 7.34 (%d.b) of the shelled seeds, and 4.73, 4.19, 4.46 (%d.b) of the unshelled sunflower seeds, respectively. Dimensions, geometric mean diameter, sphericity, and surface area values of sunflower seeds showed statistically significant differences in terms of genotypes ($p<0.01$). The sphericity values were highest in 09 TRÇ 004 genotype (43.12%) in shelled seeds and in AYBAK-2013-12-DAÇ13099 genotype (40.51%) in unshelled seeds. The effect of genotypes on the investigated volumetric characteristics was found to be statistically significant ($p<0.01$). The highest L^* color characteristic gave higher values in the AYBAK-2013-12-DAÇ13099 genotype. The angle of repose values changed from 12.65° to 15.84° on the rubber surface of the shelled sunflower seeds. The static friction coefficient values were found in the range of 0.384-0.408 on the rubber surface of the shelled sunflower seeds. The engineering characteristics of shelled and unshelled seeds of different sunflower genotypes will contribute as important technical data in the design of machinery, facilities, and systems to be used for sowing, harvesting, and threshing mechanization and post-harvest technologies.

Keywords: Sphericity, hue angle, friction surfaces, sunflower genotypes

Farklı Genotiplere ait Kabuklu ve Kabuksuz Çerezlik Ayçiçeği Tohumlarının Bazı Mühendislik Karakteristikleri

Öz: Bu çalışmada, AYBAK-2013-12-DAÇ13099, AYBAK-2013-17-DAÇ130104 09 TRÇ 004 genotiplerine ait çerezlik ayçiçeği kabuklu ve kabuksuz tohumlarının mühendislik karakteristikleri belirlenmiştir. Çalışmada kullanılan ayçiçeği genotiplerinin kabuklu tohumlarının nem içerikleri sırasıyla %7.22, %7.08, %7.34 olarak kabuksuz ayçiçeği tohumlarının ise sırasıyla %4.73, %4.19 ve %4.46 (k.b) olarak belirlenmiştir. Kabuklu ve kabuksuz ayçiçeği tohumlarının geometrik özelliklerden boyutlar, geometrik ortalama çap, küresellik ve yüzey alanı değerleri, genotipler açısından istatistiki olarak önemli farklılık göstermiştir ($p<0.01$). Küresellik değerleri kabuklu tohumlarda 09 TRÇ 004 genotipinde (%43.12), kabuksuz tohumlarda AYBAK-2013-12-DAÇ13099 genotipinde (%40.51) en yüksek değerler vermiştir. Genotiplerin incelenen hacimsel özellikler üzerindeki etkisi istatistiki olarak ($p<0.01$) önemli bulunmuştur. En yüksek L^* renk karakteristiği, AYBAK-2013-12-DAÇ13099 genotipinde daha yüksek değer vermiştir. Doğal yığılma açısı değerleri, kabuklu ayçiçeği tohumlarında en yüksek lastik yüzeyde 12.65°-15.84° aralığında bulunmuştur. Statik sürtünme katsayısı değerleri, kabuklu ayçiçeği tohumlarında en yüksek lastik yüzeyde 0.384-0.408 aralığında bulunmuştur. Farklı ayçiçeği genotiplerine ait kabuklu ve kabuksuz tohumlarının mühendislik karakteristikleri, ekim, hasat ve harman mekanizasyonu ile hasat sonrası teknolojilerine ait kullanılacak makine, tesis ve sistemlerin tasarımında önemli teknik veriler olarak katkı sunacaktır.

Anahtar kelimeler: Küresellik, hue açısı, sürtünme yüzeyleri, ayçiçeği gentotipleri

1. Introduction

The importance of oilseed plants, which have a great place in human nutrition, is understood more and more every day. Sunflower, which is one of the oilseed plants, is one of the oil plants that has a very important place in the world and in Turkey (Dökülen, 2021). Sunflower (*Helianthus annuus* L.), being one of the most important oil crops grown, is also consumed as a confectionery. In addition, the inner part of the sunflower seed is used in the production of products such as cakes, cookies, bread, chocolate, and ice cream (Lofgren, 1997).

Confectionery sunflower varieties are black, white, black with white stripes, and are larger than oil sunflower seeds. It has a high percentage of bark and a thicker stem loosely attached to the core. The shell is easily separated from the seed and allows the shell of the seed as a whole to be removed (Fernandez-Martinez et al., 2009; Hladni et al., 2012). The most important production criteria that increase the market value of the products in Confectionery varieties; are seed yield, seed protein content, 1000 seed mass, husk/seed ratio, and seed separability from the husk.

The internal rate of sunflower seeds consumed as a confectionery should be at least 50%, and the thousand seed mass should be greater than 80 grams (Lofgren, 1978). According to Lofgren (1978), confectionery sunflower seeds are divided into 3 groups according to their diameter (size). Grade 1 grains with a ratio of 15-25% on an 8.7 mm sieve are used as confectionerys. Grade 2 seeds on 8.7-7.1 mm sieves, which make up 40-60% of the whole product, are used in unshelled confectionerys or confectionery and bakery products. Grade 3 grains below 7.1 mm, which make up 15-20% of the whole product, are considered bird seeds.

According to TUIK data, sunflower for confectionerys was produced in Turkey in 2010 on a cultivation area of 900 000 decares of 150 000 tons and the yield was 167 kg da-1; For 2021, 200 000 tons of production is in question on 898 415 ha area and 223 kg da-1 yield has been reached (TUIK, 2021). Over a 12-year period, an increase of 33.33% in production values and a 33.53% increase in yield values was observed.

Meeting the food demand of the increasing world population is possible by increasing the quality and quantity of the product obtained from the unit area. Increasing the yield obtained from the unit area is realized by the use of high-quality seeds, as well as the use of many agricultural techniques. The engineering characteristics such as geometric, gravimetric characteristics, color characteristics, friction coefficient and angle of repose of sunflower seeds have great importance in terms of designing and projecting machinery and systems to be used in agricultural production from planting to harvest and post-harvest processes, classification, transportation and storage (Baryeh, 2001).

Size distribution data of sunflower seeds are essential for the design of cleaning, sorting, and separation equipment. At the same time, gravimetric properties are used for the design of equipment related to ventilation, drying, storage, and transportation (Kachru et al., 1994). Bulk density is used to determine the capacity of storage and handling systems. The angle of repose and friction characteristics are recognized by engineers as important features related to the rational design of silos and other storage structures affected by flow behavior (Kachru et al., 1994).

Studies on sunflower's engineering characteristics have been carried out by many researchers. Gupta & Das (1997), physical properties of Mordan sunflower variety seeds; Seifi & Alimardani (2010) determined the change of physical properties of sunflower seeds depending on their moisture content; Jafari et al., (2011) reported the mechanical properties of Shamshiri sunflower variety seeds, Gül et al. (2022), examined the physical, color and mechanical properties of seeds of oil sunflower varieties (Tunca, Reyna, Tarsan-1018).

The aim of this study is to determine the engineering characteristics (geometric, gravimetric characteristics, color characteristics, friction coefficient, and angle of repose) of shelled and unshelled sunflower seeds belonging to different confectionery genotypes (AYBAK-2013-12-DAÇ13099 and AYBAK-2013-17-DAÇ130104, and 09 TRÇ 004). Genotypes such as AYBAK-2013-12-DAÇ13099 and AYBAK-2013-17-DAÇ130104 are improvement lines and 09 TRÇ 004 is hybrid. With the results to be obtained from the study, it is thought that confectionery sunflower seeds will contribute to data acquisition in engineering applications for the design and development of machinery, facilities, and systems to be used in sowing, harvesting, and post-harvest processing technologies.

2. Materials and methods

Confectionery sunflower seeds, whose germination and viability were tested, were obtained from the Field Crops Department of the Faculty of Agriculture of Gaziosmanpaşa University. Seeds of sunflower genotypes were stored at 18.5ºC and 47% humidity before test. The engineering characteristic measurements of sunflower genotypes were carried out in the Biological Materials Laboratory of the Biosystem Engineering Department of Tokat Gaziosmanpaşa University, Faculty of Agriculture, between 15-30 September 2021. For the measurements, damaged and broken materials in sunflower seeds were removed from the samples. In this study, the sunflower genotypes such as [AYBAK-2013-12-DAÇ13099 (Improvement line) and AYBAK-2013-17-DAÇ130104 (Improvement line) and 09 TRÇ 004 (Hybrid)], were used (Figure 1).

The moisture content of the samples belonging to the sunflower genotypes was determined after drying the samples in a dry oven (oven) at a temperature of 105±1°C and for 24 hours on a dry basis (%d.b) (Suthar & Das, 1996). AYBAK-2013-12-DAÇ13099 and AYBAK-2013-17-DAÇ130104, and 09 TRÇ 004 genotypes have 7.22%, 7.08%, and 7.34% (d.b.) moisture content values for shelled seeds, respectively, and for unshelled seeds have 4.73%, 4.19% and 4.46% (%d.b), respectively.

Figure 1. Examples of the sunflower confectionery genotypes used in the study
Şekil 1. *Çalışmada kullanılan çerezlik ayçiçeği genotiplerine ait örnekler*

2.1. Geometric and gravimetric characteristics

In order to determine the geometric and volumetric characteristics of shelled and unshelled sunflower seeds were used 100 random samples. The length (*l*, mm), width (*w*, mm), and thickness (*t*, mm) were determined with a digital caliper with 0.01 mm precision (Figure 2). The geometric mean diameter (d_g), sphericity (S_p), and surface area (S_a) were determined from the following equations given by Mohsenin, 1980).

$$d_g = (l\,.w.\,t)^{1/3} \quad (1)$$

$$S_p = (d_g/l)100 \quad (2)$$

$$S_a = \pi\,(d_g)^2 \quad (3)$$

Figure 2. Size measurement of a sample confectionery sunflower seed
Şekil 2. *Örnek bir çerezlik ayçiçeği tohumunun boyut ölçümü*

Seed mass (M_a) was measured with a digital electronic balance with an accuracy of 0.001 g. For the measurement of thousand seed masses (T_m), 100 sample masses were taken in 4 replicates. The hectoliter method was used for the bulk density (B_d). The following equation was used for the seed volume (V_o).

$$V_o = \pi/6\,(l\,.w.\,t) \quad (4)$$

2.2. Color characteristics

To determine the color characteristics of shelled and unshelled sunflower seeds, Minolta CR-400 Model (Tokyo, Japan) colorimeter device was used, considering CIE, L^*, a^*, and b^* color scales. The seeds were measured both shelled and unshelled seeds by taking the average value of all three measurements. According to the color scale changes, the redness-greenness (a^*) value, yellowness-blueness (b*) value as well as the hue angle ($H_a{}^o$) and chroma (C_r)value were determined by the following equations (McGuire, 1992). The chroma value (C_r) of seeds is close to 0 for pastel tones and 100 for vibrant tones as an indicator of vivid or pastel tone of seeds (Günaydın, 2020).

$$H_a{}^o = \tan^{-1}(b^*/a^*) \quad (5)$$

$$C_r = (a^{*2} + b^{*2})^{1/2} \quad (6)$$

2.3. Mechanical characteristics

Friction surfaces such as PVC, laminated galvanized steel, rubber, and plywood were used to measure the friction coefficients of sunflower seeds, and the friction measurement device was given in Figure 4 (Yılmaz & Altuntas, 2020). For the friction coefficient measurement, the inclination angle (tanα) at the time when the seeds first started to move from different surfaces in the device that can be tilted with a screwed arm was taken into account.

Figure 3. Static friction coefficient measurement
Şekil 3. *Statik sürtünme katsayısı ölçümü*

For the determination of the angle of repose (A_r), a cylinder with 300 x 500 mm dimensions and an empty upper and the lower part was used, the seeds were filled to the top and raised to a cone formation on a flat plate surface. The angle of repose (A_r) of sunflower seeds was determined by the following equations (Kaleemullah & Gunasekar, 2002). The results were evaluated by using different surfaces (galvanized steel, plywood, rubber) for the angle of repose.

$$A_r = tan^{-1} (h / r) \qquad (7)$$

Where;
r is the cone base radius (cm)
h is the cone height (cm).

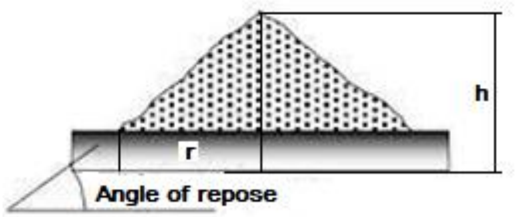

Figure 4. Measurement of the angle of repose
Şekil 4. *Doğal yığılma açısının ölçümü*

2.4. Statistical analysis

Kolmogorov-Smirnov test of normality was used to determine whether the data obtained in the study were suitable for normal distribution. It was determined that the normality tests before the analysis of the variance of the data were suitable for statistical analysis on the measurements of all studied engineering properties of the shelled and unshelled seeds of the sunflower genotypes. No transformation was applied for any of the measured properties. By using a one-way analysis of variance in the study, the effect of genotypes on the parameters examined with the DUNCAN multiple comparison tests was determined (SPSS, 2000).

3. Results and discussion

3.1. Geometric characteristics

The geometric and gravimetric characteristics values and variance analysis results are given in Tables 1 and 2 for AYBAK-2013-12-DAÇ13099 and AYBAK-2013-17-DAÇ130104, and 09 TRÇ 004 genotypes both shelled seeds and unshelled seeds, respectively. Statistically significant (p<0.01) differences were observed among the varieties in terms of geometric characteristics of the shelled and unshelled seeds. The length (23.95 mm) and width (7.96 mm) values gave high values for the shelled seeds of the AYBAK-2013-17-DAÇ130104 genotypes, and the length (14.56 mm) values of the width (5.25 mm) values for the unshelled seeds of the 09 TRÇ 004 genotype are higher than the other genotypes.

Table 1. The geometric characteristics of shelled sunflower seeds with different genotypes
Çizelge 1. *Farklı genotiplere ait kabuklu ayçiçeği tohumlarının geometrik özellikleri*

Genotypes	*l (mm)*	*w (mm)*	*t (mm)*	*d_g (mm)*	*S_p (%)*	*S_a (mm²)*
AYBAK-2013-12-DAÇ13099	19.52±0.1975c**	7.18±0.1044b**	3.70±0.0463c**	8.00±0.0677c**	41.07±0.3234b**	202.35±3.3386c**
AYBAK-2013-17-DAÇ130104	23.95±0.1533a**	7.96±0.0852a**	4.16±0.0473b**	9.22±0.0691a**	38.58±0.2842c**	268.03±4.0156a**
09 TRÇ 004	20.99±0.0777b**	7.85±0.0634a**	4.53±0.0404a**	9.03±0.0493b**	43.12±0.2259a**	256.93±2.7799b**
F value	***222.68***	***24.18***	***85.15***	***109.69***	***65.59***	***105.95***

l: length, w: width, t: thickness, d_g: geometric mean diameter, S_p: sphericity, S_a: surface area, ±: standard error
***p<0.01. The difference between the same letters in the same column is insignificant.*

Table 2. The geometric characteristics of unshelled sunflower seeds with different genotypes
Çizelge 2. *Farklı genotiplere ait kabuksuz ayçiçeği tohumlarının geometrik özellikleri*

Genotypes	*l (mm)*	*w (mm)*	*t (mm)*	*d_g (mm)*	*S_p (%)*	*S_a (mm²)*
AYBAK-2013-12-DAÇ13099	12.34±0.1412c**	4.45±0.0396c**	2.29±0.0182b**	4.99±0.0344b**	40.51±0.2991a**	78.86±1.0719b**
AYBAK-2013-17-DAÇ130104	14.56±0.0692a**	4.78±0.0389b**	2.50±0.346a**	5.56±0.0365a**	38.26±0.2011b**	97.49±1.3163a**
09 TRÇ 004	13.84±0.1231b**	5.25±0.0459a**	2.44±0.0319a**	5.60±0.0271a**	40.48±0.3185a**	98.48±0.9712a**
F value	***96.29***	***92.06***	***14.32***	***104.90***	***21.47***	***95.81***

l: length, w: width, t: thickness, d_g: geometric mean diameter, S_p: sphericity, S_a: surface area,
*±: standard error **p<0.01. The difference between the same letters in the same column is insignificant.*

The higher sphericity values were found in shelled seeds with a value of 43.12% in 09 TRÇ 004 genotype and 40.51% in unshelled seeds in AYBAK-2013-12-DAÇ13099 genotypeThe surface area values gave higher values as 268.03 mm^2 value for AYBAK-2013-17-DAÇ130104 genotype in shelled sunflower seeds and 98.48 mm^2 value in 09 TRÇ 004 genotype in unshelled sunflower seeds compared to other genotypes (Table 1, Table 2).

Seifi & Alimardani (2010) found that the length values of the SHF8190 sunflower variety seeds changed from 12.14 mm to 12.60 mm, the width values varied from 5.79 mm to 6.37 mm, the thickness values ranged from 3.85 mm to 4.09 mm, and the sphericity values between 52.82% and 55.42% for the different moisture contents (4%-22%). Gupta & Das (1997), found that the width values varied from 3.59 mm to 4.93 mm, and the thickness values changed from 2.09 mm to 2.72 mm for unshelled Mordan sunflower variety seeds at a moisture content of 6.2%. Jafari et al. (2011) found that the geometric mean diameter was between 5.74 and 10.63 mm and surface area values were changed from 103.5 to 354.9 mm^2 for seeds of shelled Shamshiri sunflower variety, while the geometric mean diameter was between 3.24 and 6.47 mm, and surface area values were varied from 5.74 mm and 10.63 mm for seeds of unshelled Shamshiri sunflower variety, respectively. According to the results of the literature, the geometric mean diameter and surface area of the shelled sunflower and unshelled sunflower seeds showed close values, while the sphericity values in the study found were lower than Seifi and Alimardani (2010).

3.2. Gravimetric Characteristics

The gravimetric characteristics of shelled and unshelled seeds of sunflower genotypes are given in Tables 3 and 4. While the higher values for seed masses were found as 0.164 g and 0.098 g in shelled and unshelled seeds of the 09 TRÇ 004 genotype respectively, the highest values in terms of seed volume were observed in the AYBAK 2013-17-DAÇ130104 genotype. The effect of genotypes was significant ($p<0.01$) and the differences between genotypes were remarkable in the statistical analyzes of all examined volumetric properties.

Table 3. The gravimetric characteristics of shelled sunflower seeds with different genotypes
Çizelge 3. *Farklı genotiplere ait kabuklu ayçiçeği tohumlarının gravimetrik özellikleri*

Genotypes	M_a (g)	T_m (g)	V_o (mm^3)	B_d (kg m^{-3})
AYBAK-2013-12-DAÇ13099	0.120±0.0027c**	137.24±2.2861c**	274.90±6.6586c**	244.12±1.0820a**
AYBAK-2013-17-DAÇ130104	0.149±0.0028b**	173.37±0.0736b**	417.66±9.3918a**	227.02±2.9984b**
09 TRÇ 004	0.164±0.0024a**	188.85±2.3813a**	391.18±6.3049b**	248.84±4.4410a**
F value	***69.84***	***193.05***	***100.42***	***13.23***

*M_a: seed mass, T_m: thousand-grain weight, V_o: seed volume, B_d: bulk density. ±: standard error, **p<0.01. The difference between the same letters in the same column is insignificant.*

Table 4. The gravimetric characteristics of unshelled sunflower seeds with different genotypes
Çizelge 4. *Farklı genotiplere ait kabuklu ayçiçeği tohumlarının gravimetrik özellikleri*

Genotypes	M_a (g)	T_m (g)	V_o (mm^3)	B_d (kg m^{-3})
AYBAK-2013-12-DAÇ13099	0.069±0.0023c**	61.90±2.7463c**	66.10±1.3031b**	473.91±2.8354b**
AYBAK-2013-17-DAÇ130104	0.087±0.0015b**	83.70±1.486b**	91.46±1.8653a**	461.98±4.3907c**
09 TRÇ 004	0.098±0.0033a**	95.91±0.7740a**	92.86±1.4306a**	517.17±3.8714a**
F value	***34.86***	***86.01***	***94.22***	***59.81***

*M_a: seed mass, T_m: thousand-grain weight, V_o: seed volume, B_d: bulk density. ±: standard error, **p<0.01.*
The difference between the same letters in the same column is insignificant.

Gupta & Das (1997) found that the seed masses were 0.049 g in shelled sunflower seed and 0.034 g in unshelled sunflower for the Mordan variety. According to the results of the literature, the seed masses values found were found to be higher than in this study. Polatlı (2013) found that the shelled sunflower seeds were classified into 4 different populations (populations 1, 2, and 3 in the F3 generation, whereas 4 populations in the F4 generation) determined the thousand seed masses as 100.26 g, 124.24 g, 101.89 g, and 116.80 g, respectively. Seifi and Alimardani (2010) found that the seed volumes of sunflower seeds were changed from 148.96 mm^3 to 177.81 mm^3 depending on the moisture content (4%, 12%, 16%, and 22%) for the Shamshiri variety. The shelled seeds gave higher values in terms of seed mass and seed volume than the unshelled seeds, in the study. Thousand seed mass and seed volume values of the shelled sunflower seeds gave higher values in this study than the varieties given in the literature. The reason for the change in these results is thought to be due to the differences in the varieties of genotypes used in the studies, as well as the climate and soil factors in which the seeds were grown.

3.3. Color Characteristics

The results of the color characteristics of the shelled and unshelled seeds of the sunflower genotypes are given in Tables 5 and 6. The highest $L*$ characteristic was found in shelled and unshelled AYBAK-2013-12-DAÇ13099 genotype seed. Hue angle and chroma values calculated by using $L*$, $a*$, and $b*$ color characteristic values were also found to be higher in unshelled seeds in the AYBAK-2013-12-DAÇ13099 genotype. $L*$ and $a*$ color characteristics were statistically different at p<0.01 level for shelled sunflower seeds, while the difference between genotypes was statistically insignificant in unshelled sunflower seeds.

Gul et al. (2022), among the seeds of oil sunflower varieties, the color characteristics of Tunca variety $L*$, $a*$, and $b*$ values were determined as 23.44, 0.88, and 1.50, respectively; These values changed to 21.82, 0.81, and 1.24 in Reyna variety. While the difference between varieties on $L*$ and $a*$ color characteristics was insignificant, a p<0.01 difference was observed between varieties on $b*$ and chroma color characteristics. It was determined that $L*$ brightness values were higher in the Tunca variety.

Table 5. Color characteristics of shelled sunflower seeds with different genotypes
Çizelge 5. *Farklı genotiplere ait kabuklu ayçiçeği tohumlarının renk özellikleri*

Genoypes	*L**	*a**	*b**	C_r	H_a
AYBAK-2013-12-DAÇ13099	76.71±0.6907a**	4.72±0.1098a**	10.10±0.3609a*	11.16±0.3438a*	64.83±0.7859^{ns}
AYBAK-2013-17-DAÇ130104	72.27±0.6391b**	4.66±0.0779a**	9.68±0.3847ab*	10.75±0.3621a*	64.07±0.7978^{ns}
09 TRÇ 004	64.45±0.6621c**	4.14±0.0622b**	8.96±0.1222b*	9.87±01243b*	65.17±0.3409^{ns}
F value	***87.31***	***13.64***	***3.43***	***4.92***	***0.70***

±: standard error, ^{ns}: nonsignificant, * p<0.05, **p<0.01.
The difference between the same letters in the same column is insignificant.

Table 6. Color characteristics of unshelled sunflower seeds with different genotypes
Çizege 6. *Farklı genotiplere ait kabuksuz ayçiçeği tohumlarının renk özellikleri*

Genotypes	*L**	*a**	*b**	C_r	H_a
AYBAK-2013-12-DAÇ13099	54.37±0.9337^{ns}	3.94±0.0730^{ns}	8.12±0.2605a**	9.03±0.2571a**	64.00±0.5419a*
AYBAK-2013-17-DAÇ130104	52.96±1.0967^{ns}	3.79±0.0573^{ns}	7.27±0.2821b**	8.20±0.2540b**	62.25±0.9350ab*
09 TRÇ 004	54.27±0.7914^{ns}	3.83±0.686^{ns}	6.95±0.1137b**	7.94±0.0983b**	61.08±0.6472b*
F value	***0.69***	***1.44***	***6.85***	***6.90***	***4.05***

±: standard error, ^{ns}: nonsignificant, * p<0.05, **p<0.01.
The difference between the same letters in the same column is insignificant.

3.4. Mechanical characteristics

Angle of repose

The angle of repose values of shelled and unshelled sunflower seeds with different genotypes was examined on galvanized steel, plywood, and rubber surfaces, and the results are given in Tables 7 and 8. In sunflower genotypes, the highest value of angle of repose was found on the rubber surface for shelled sunflower seeds, while the highest value was observed on the plywood surface for unshelled sunflower seeds. According to the values of the angle of repose of the sunflower genotypes on different surfaces, statistically, significant differences were found between the shelled sunflower genotypes (p<0.01), while it was statistically insignificant in the unshelled sunflower seeds. While the angle of repose values was found to be between 12.65° and 15.84° on the rubber surface in shelled sunflower seeds, the values between 13.32° and 15.15° on the plywood surface in unshelled sunflower seeds were determined (Table 7, 8).

Table 7. The angle of repose values of shelled sunflower seeds with different genotypes
Çizelge 7. *Farklı genotiplere ait kabuklu ayçiçeği tohumlarının doğal yığılma açısı değerleri*

Genotypes	*Galvanized steel*	*Plywood*	*Rubber*
AYBAK-2013-12-DAÇ13099	8.60±0.3642b*	11.37±0.7652b**	12.65±0.5594b**
AYBAK-2013-17-DAÇ130104	8.37±1.0816b*	11.49±0.5539b**	13.26±0.6910b**
09 TRÇ 004	11.14±0.6812a*	14.47±0.5212a**	15.84±0.5911a**
F value	***4.01***	***7.95***	***7.52***

±: standard error *p<0.05, **p<0.01.
The difference between the same letters in the same column is insignificant.

Table 8. The angle of repose values of unshelled sunflower seeds with different genotypes
Çizelge 8. *Farklı genotiplere ait kabuksuz ayçiçeği tohumlarının doğal yığılma açısı değerleri*

Genotypes	*Galvanized steel*	*Plywood*	*Rubber*
AYBAK-2013-12-DAÇ13099	12.79±0.3719a**	15.15±0.7625^{ns}	12.94±0.2690^{ns}
AYBAK-2013-17-DAÇ130104	11.75±0.4187a**	13.59±0.4075^{ns}	11.76±0.4518^{ns}
09 TRÇ 004	9.54±0.5253b**	13.32±0.6222^{ns}	13.16±0.8684^{ns}
F value	***13.97***	***2.60***	***2.18***

±: standard error, ^{ns}: nonsignificant, **p<0.01.
The difference between the same letters in the same column is insignificant.

Gupta & Das (1997) found that the angle of repose values changed from 34° to 41° in shelled sunflower seeds of the Mordan variety, while they varied from 27° to 38° for unshelled sunflower seeds. Accordingly, the values observed in this study were lower than the literature values. The reason for this difference is thought to be due to the difference in the ecological conditions and soil characteristics in which the seeds are grown, together with the variety used.

Static friction coefficient

The results of the static friction coefficient values of shelled and unshelled sunflower seeds with different genotypes on galvanized steel, plywood, PVC, rubber, and laminate surfaces as different friction surfaces are given in Tables 9 and Table 10. According to the variance analysis results statistically p<0.01 differences were observed in terms of the static friction coefficients used on laminate, galvanized steel, and plywood friction surfaces in shelled sunflower seeds on the basis of genotypes (Table 9, Table 10). While the static friction coefficient values were found to be between 0.384 and 0.408 on the rubber surface in shelled sunflower seeds according to the genotypes, it was between 0.384 and 0.433 on the plywood surface in unshelled sunflower seeds. Altuntas et al. (2005) found that the static friction coefficients of fenugreek seeds ranged from 0.464 to 0.567 for the plywood surface when the moisture content rises from 8.9% to 20.1%. In the study, friction coefficient values gave higher results on rubber surfaces in shelled seeds and on plywood surfaces in unshelled seeds than on the other surfaces.

Khodabakhshian et al. (2010) found that the static friction coefficient values for galvanized steel, rubber, and plywood surfaces were as 0.38, 0.50 and 0.46. in Shahroodi variety sunflower seeds at 7% moisture content, respectively. Accordingly, the friction coefficient values found for the rubber surfaces for the shelled sunflower seeds in this study were found to be lower than the literature value.

Table 9. The static friction coefficient of shelled sunflower seeds with different genotypes
Çizelge 9. *Farklı genotiplere ait kabuklu ayçiçeği tohumlarının statik sürtünme katsayıları*

Genotypes	*PVC*	*Galvanized Steel*	*Laminate*	*Plywood*	*Rubber*
AYBAK-2013-12-DAÇ13099	0.236±0.0048^{ns}	*0.302±0.0047b*****	*0.213±0.0055a*****	*0.279±0.0058b*****	*0.398±0.0052ab**
AYBAK-2013-17-DAÇ130104	0.231±0.0047^{ns}	*0.292±0.0040b*****	*0.203±0.0041a*****	*0.294±0.0058b*****	*0.384±0.0067b**
09 TRÇ 004	0.242±0.0056^{ns}	*0.319±0.0058a*****	*0.184±0.0040b*****	*0.317±0.0086a*****	*0.408±0.0051a**
F value	***0.32***	***7.68***	***10.64***	***7.81***	***4.50***

±: standard error, ^{ns}: nonsignificant, *p<0.05, **p<0.01.
The difference between the same letters in the same column is insignificant.

Table 10. The static friction coefficient of unshelled sunflower seeds with different genotypes.
Çizelge 10. *Farklı genotiplere ait kabuksuz ayçiçeği tohumlarının statik sürtünme katsayıları*

Genotypes	*PVC*	*Galvanized Steel*	*Laminate*	*Plywood*	*Rubber*
AYBAK-2013-12-DAÇ13099	0.337±0.0099a^{ns}	*0.340±0.0039a**	*0.246±0.0037*^{ns}	*0.433±0.0082a*****	*0.388±0.0040**
AYBAK-2013-17-DAÇ130104	0.313±0.0076ab^{ns}	*0.317±0.047b**	*0.238±0.0045*^{ns}	*0.412±0.0081a*****	*0.367±0.0040b**
09 TRÇ 004	0.306±0.0085b^{ns}	*0.317±0.0077b**	*0.231±0.0058*^{ns}	*0.384±0.0063b*****	*0.396±0.0081a**
F value	***3.38***	***5.56***	***2.40***	***10.39***	***6.39***

±: standard error, ^{ns}: nonsignificant, *p<0.05, **p<0.01.
The difference between the same letters in the same column is insignificant.

4. Conclusion

The engineering characteristics such as geometric, gravimetric, color, and mechanical properties of the confectionery sunflower genotypes were determined. It was observed that the *L** characteristic value of both the shelled and shellless seeds of the AYBAK-2013-12-DAÇ13099 genotype was higher, and the chroma value was higher for the shellless seed than for the other genotypes. Geometric sizes of the seeds belonging to the confectionery sunflower genotypes differ according to the genotypes, which will create differences in the design of the equipment to be used in post-harvest cleaning, classification, and separation, and it can be said that the differences in the volumetric properties may cause differences in the design of the equipment related to ventilation, drying, storage and transportation of the genotypes. In terms of mechanical properties, angle of repose and friction properties gave different results for different surfaces, and the use of both shelled and unshelled seeds in the study. In general, different sunflower genotypes gave different results for the parameters examined in the study. The reason for this is that the genotypes used in the experiment have different geometric, gravimetric, colour and mechanicial characteristics as well as genetic and cultivating characteristics. These results will cause significant differences in terms of designs in post-harvest production technologies. As a result, it is thought that the findings on sunflower seeds will create important engineering data in the design of the equipment related to sowing, harvest, cleaning, classification, and post-harvest technologies.

References

Altuntaş, E., Özgöz, E., & Taşer, Ö.F. (2005). Some physical properties of fenugreek (*Trigonella foenum-graceum* L.) seeds. *Journal of Food Engineering*, 71(1), 37–43.

Baryeh, E.A. (2001). Physical properties of bambara groundnuts. *Journal of Food Engineering*, 47(4), 321-326.

Dökülen, Ş. (2021). Ayçiçeğinde (*Helianthus annuus* L.) farklı sıklık ile tohumluk kaplama uygulamalarının verim ve kalite özelliklerine etkileri. [*Yayınlanmamış doktora tezi*]. Tokat Gaziosmanpaşa Üniversitesi Lisansüstü Eğitim Enstitüsü Tarla Bitkileri Anabilim Dalı. S. 205. Tokat.

Fernandez-Martinez J.M., Perez-Vich B. & Velasco L. (2009). Sunflower. In: Vollmann J, Rajčan I, eds. Oil crops: Handbook of plant breeding. The Netherlands: Springer, pp. 155–232.

Gupta, R.K., & Das, S.K. (1997). Physical properties of sunflower seeds. *Journel Agricultural Engineering Research*, 66, 1–8.

Gül, E.N., Altuntaş, E., & Gök, H. (2022). Farklı Ayçiçeği Çeşitlerine Ait Tohumların Bazı Fiziksel ve Renk Karakteristikleri ile Mekanik Davranışlarının Belirlenmesi. *Anadolu Tarım Bilimleri Dergisi*, 37(2), 421-437.

Günaydın, S. (2020). Mikrodalga, konvektif ve gölgede kurutma yöntemleri kullanılarak kurutulmuş kuşburnu meyvesinin kurutma kinetiği, renk ve besin elementi içeriği açısından incelenmesi. [*Yayınlanmamış yüksek lisans tezi*]. Bursa Uludağ Üniversitesi Fen Bilimleri Enstitüsü, s: 65, Bursa.

Hladni, N., Miklič, V., Jocić, S., Jocković, M., Radeka, I., & Lečić, N. (2012). Determining the influence of yield components on the confectionary sunflower seed yield. In: Proceedings of 53rd Conference of Oil Industry. Production and Processing of Oilseeds, Herceg Novi, Montenegro, 55–62.

Jafari S., Khazaei, J., Arabhosseini A., Massah J., & Khoshtaghaza, M.H. (2011) Study on mechanıcal propertıes of sunflower seeds. *Electronıc Journal of Polish Agricultural Unıversıtıes*. 14(1): #06.

Kachru, R.P., Gupta, R.K., & Alam, A. (1994). Physicochemical Constituents & Engineering Properties. Jodhpur, India: Scientific Publishers.

Kaleemullah, S., & Gunasekar, J.J. (2002). Moisture-dependent physical properties of arecanut kernels. *Biosystem Engineering*, 82(3): 331-338.

Khodabakhshian, R., Emadi, B., & Abbaspour Fard, M.H. (2010). Some engineering properties of sunflower seed and ıts unshelled. *Journal of Agricultural Science and Technology*, 4(4): 37-46.

Lofgren, J.R. (1978). Sunflower for confectionery food, bird food and pet food. In J.F. Carter (ed) Sunflower Technology and Production. ASA. SCSA. SSSA Monograph No:19.Madisaon.WI. pp. 441-456.

Lofgren, J.R. (1997). Sunflower for Confectionery Food, Birdfood and Pet Food. In A. A. Schneiter Sunflower Technology and Production ASA SCSA and SSSA Monograph No: 35. Madison WI. P. 747-764.

McGuire, R.G. (1992). Reporting of objective colmeasurements. *Hortscience*, 27: 1254-1255.

Mohsenin, N.N. (1980). Physical properties of plants and animal materials. Gordon and Breach Science publishers, NW, New York.

Polatlı, O. (2013). Çerezlik ayçiçeği (*Helianthus annuus* L.) populasyonlarında dane özellikleri ve özellikler arası ilişkiler. Yüksek Lisans Tezi, Adnan Menderes Üniversitesi Fen Bilimleri Enstitüsü, Tarla Bitkileri Anabilim Dalı. s. 52, Aydın.

Seifi, M.R., & Alimardani, R. (2010). Moisture-dependent physical properties of sunflower seed (SHF8190). *Modern Applied Science*, 4(7): 135-143.

SPSS, (2000). "SPSS for Windows". Student Version. Release 10.0.9 SPSS Inc IL USA.

Suthar, S.H., & Das, S.K. (1996). Some physical properties of Karingda [Citrus lanatus (thumb) mansf] grains. *Journal ofAgricultural Engineering Research*, 65: 15-22.

TUİK, (2021). Türkiye İstatistik Kurumu, Yağlı Tohumlar. https://data.tuik.gov.tr/Kategori/GetKategori?p=tarim-111

Yılmaz, G., & Altuntas, E. (2020). Some bio-technical properties of flax seeds, fennel seeds and harmal seed capsules. *Turkish Journal of Agricultural Engineering Research (TURKAGER)*, 1(2), 222-232.