J. of Soil Sciences and Agricultural Engineering, Mansoura Univ., Vol. 12 (12):855 -859, 2021

Journal of Soil Sciences and Agricultural Engineering

Journal homepage: www.jssae.mans.edu.eg
Available online at: www.jssae.journals.ekb.eg

Identification of some Physical and Mechanical Properties of Maize Grains

Reem H. Mohamed[1*]; A. M. El Shal[1] and O. A. Omar[2]

[1]Department of Agricultural Engineering, Zagazig University, Zagazig 44519, Egypt
[2]Agricultural Engineering Institute, Agriculture Research Center, El Doki, Egypt

Cross Mark

ABSTRACT

The importance of maize for human, livestock and poultry regarding to use as feed or as dry feed industry. Physical and mechanical properties of maize grains are important to design the planter/seeder (hopper, metric device, tube), grading machines and to select members and storage equipment. So, this study aimed to determine the maize grain physical and mechanical properties for new varieties, namely hybrid single cross Hi-Tech white and hybrid single cross 168 yellow which use as relative parameters for designing machines . One hundred of maize grains were chosen at random from two maize varieties hybrid single cross Hi-Tech white and hybrid single cross 168 yellow. The results found for maize grains of the Hi--Tech and hybrid 168 maize varieties, the mean length, width, thickness, surface area, projected area, kernel volumes, arithmetic diameter, geometric mean diameter, sphericity, and aspect ratio were (10.63-10.02 mm),(10.00-8.29 mm), (5.28-4.81 mm), (211.84-169.07 mm^2), (83.75-65.36 mm^2), (291.6-207.96 mm^3), (8.64-7.71 mm), (8.20-7.32 mm) ,(77.77-73.37 %), and (94.77-82.93 %) ,respectively. True density, bulk density, and porosity were (1.42 - 1.28 g/cm^3), (0.850 - 0.775 g/cm^3), and (39.89 - 39.12%) for Hi-Tech and Hybrid 168 maize varieties, respectively. Hi-Tech and Hybrid 168 maize varieties had a mean angle of repose of 24.59° and 25.90°, respectively. The mean static coefficients of friction for maize grains (Hi-Tech and Hybrid 168 maize varieties) against four different surfaces (wood, plastic, steel, and glass) were (0.44 - 0.48), (0.36 - 0.38), (0.20 - 0.24) and (0.30 - 0.34), respectively.

Keywords: Arithmetic diameter; Geometric mean diameter; Grain volumes; Maize; projected area; Surface area

INTRODUCTION

Maize (*Zea mays*) is the main cereal crop worldwide to its importance for human, animal, and poultry feed as in dry feed industry by up to 70 %, on bread ingredients by 20 %, as interference in some industries, such as obtaining glucose, fructose, and oil. It constitutes a staple food in many regions of the world. In addition to that, maize represents the third-largest crop after rice and wheat, (Ministry of Agriculture-Egypt, 2021). In Egypt, the maize cultivated area is about 2.23 million feddan which produces annually 7.3 million ton of maize grains approximately (FAO, 2018). Daboul *et al*., (2011) found that the average of length, width, thickness were (0.9 - 0.96), (0.86 - 0.77), and (0.54 - 0.50) for corn 10 and corn 162 respectively. The mass, volume, true density, and bulk density of 1000 seeds for the studied varieties were (282.3 - 250.4 g), (364.16 - 337.99 cm^3), (1.34 - 1.28 g/cm^3), and (0.775 - 0.741 g/cm^3). The static coefficient friction for the surfaces galvanized iron, mild-steel, plywood were (0.531 - 0.459), (0.572 - 0.549), (0.624 - 0.586) for corn 10 and corn 162 respectively. Corn 10 variety recorded the highest value in the dynamic angle of repose (32.6°). While the Corn 162 variety showed the lowest value (28.8°). Ismail (2015) indicated that there are a relationship between seed dimensions and each of hole diameter, metering breadth and thickness of feeding seed disk. Soyoye *et al*., (2018) said that The ability to understand some of these seeds' physical and mechanical properties is useful for developing agricultural machines and equipment for planting, harvesting, processing, packing, and storage. The length, width, thickness, geometric mean diameter, surface area, bulk volume, bulk density, true density, porosity, and sphericity of maize were measured and reported 1.043 cm, 0.883 cm, 0.405 cm, 0.716 cm, 1.621 cm^2, 29.200 mL, 1.169 g mL^{-1}, 1.369 g mL-^{1}, 14.599% and 0.693 respectively. Over stainless steel, galvanised steel, mild steel, and plywood, the mean angle of repose and coefficient of friction were 38.6° and 0.805, 36.7° and 0.746, 38.28° and 0.794 and 34.75° and 0.702 respectively were recorded for maize. Al-Mitewty *et al*., (2019) mentioned that because of their importance in the design of agricultural equipment and their relationship to the production operation, physical and mechanical characteristics are significant subjects to study. Kruszelnicka (2021) said that Corn grain mechanical characteristics are critical in the design of processing devices whose energy requirement is determined by these features. The goal of this research is to figure out which mechanical features of maize grains to look for, as well as the rupture energy. A static compression test was performed on an Instron 5966 testing equipment to determine the selected physical parameters (size, volume) of corn grains. The objective of this study is to determine physical and mechanical properties. So, the two varieties maize grains and to know the variation between properties for these grains that use to design, fabricate the maize planter machines for precision agriculture and save cereals worldwide

MATERIALS AND METHODS

To fulfill the objective of study, the experiment was conducted during at Kafer El Hamam Station of Agricultural Research, Governorate of El Sharkia, Egypt.

*** Corresponding author.**
E-mail address: reemhasanien130@gmail.com
DOI: 10.21608/jssae.2021.106457.1037

A sample of 100 intact grains of Hi-Tech single cross (white) and Hybrid single cross 168 (yellow) maize varieties as shown in Fig. 1 and Fig. 2 were selected randomly. Some maize grains physical and mechanical characteristics were specified as follows:

Fig. 1. Single Hi-Tech (White)

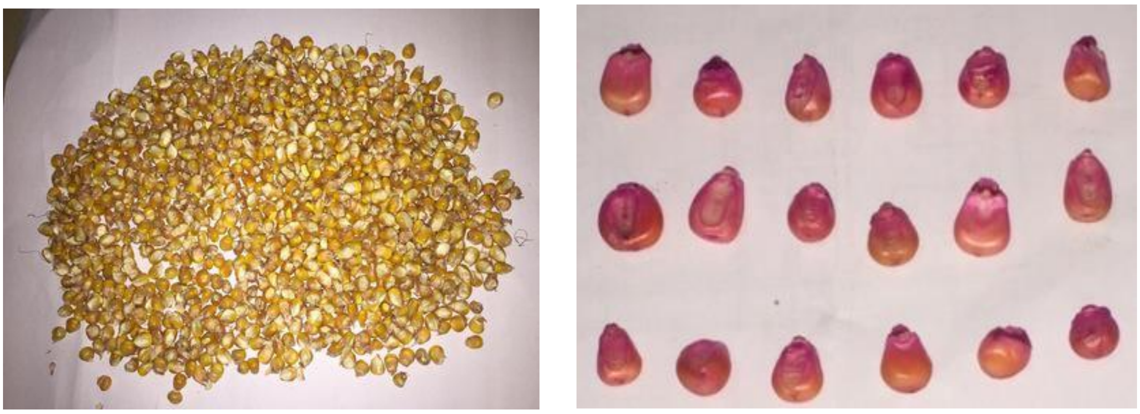

Fig. 2. Single Hybrid 168 (Yellow)

Physical properties

Size of maize grain the dimensions of the major axes are used to determine size: length (L, mm), width (W, mm) and thickness (T, mm), by a digital vernier caliper with an accuracy of 0.01 mm.

Mass measured using the digital balance with an accuracy of 0.01 g.

Arithmetic diameter and geometric diameter

The arithmetic diameter (D_a) and geometric diameter (D_g) are calculated according to Fadavi *et al*. 2013 as follows:

$$D_a = \frac{L+W+T}{3} \quad (1)$$

$$D_g = (L \,.\, W \,.\, T)^{1/3} \quad (2)$$

Where D_a is the arithmetic diameter and D_g is the geometric diameter, mm.

Sphericity (S) is calculated as cited by Perez *et al*. (2007) as follows:

$$S = \frac{D_g}{L} \times 100 \quad (3)$$

Aspect ratio (R_a) is calculated as outlined by Seifi and Alimardani, 2010 as follows:

$$R_a = \frac{W}{L} \times 100 \quad (4)$$

Surface area and projected area Surface area (S_a), and the projected area (A_p) are calculated according to Goyal *et al*. 2007 and Yildirim and Tarhan, 2016 as follows:

$$S_a = \pi \,.\, (D_g)^2 \quad (5)$$

$$A_p = \pi \,.\, \left(\frac{L \,.\, W}{4}\right) \quad (6)$$

Volume is specified as the procedure of Vursavus and Ozguven, 2004 as follows:

$$V = \frac{\pi}{6}\ L \,.\, W \,.\, T \quad (7)$$

Bulk density is specified according to Davies, 2009 as follows:

$$\rho_b = \frac{M_s}{V} \quad (8)$$

Where ρ_b is the bulk density of grains, g/cm^3, M_s is the mass of grains, g.

True density is specified according to Davies, 2009 as follows:

$$\rho_s = \frac{M}{V_t} \quad (9)$$

Where ρ_s is the true density of the individual grain, g/cm^3, M is the mass of the individual grain, g, V_t is the mass of the individual grain, cm^3.

Porosity is specified as pointed out by Altuntas and Erkol, 2010 as follows:

$$\varepsilon = \left(1 - \frac{\rho_b}{\rho s}\right) \times 100 \quad (10)$$

Where ε is porosity, (%), ρ_b is the bulk density of the grains, g/cm^3, ρ_s is the true density of individual grain, g/cm^3.

Mechanical properties

Repose angle (α) cylindrical tube of 50 mm height and 30 mm diameter was set on a clean surface and filled with grain samples was estimated. By steadily lifting and removing the cylinder, maize grain samples took on a cone shape. The cone's radius and height were measured. The angle of repose (α) was estimated using the formula of Yildirim and Tarhan, 2016 as follows:

$$\alpha = \tan^{-1}\left(\frac{L}{R}\right) \quad (11)$$

Where L is the height of cone, mm, R is the radius of cone, mm.

Coefficient of static friction the inclined surfaces (wood, plastic, steel, and glass) used to maize grain coefficient of static a friction. An infinite screw was affixed to the end of the friction surface (inclined plane). The maize grains were put in a cubic box of 20×20×10 cm^3, and then the cubic was placed on the surfaces. To avoid friction between the cubic and the surfaces, the cubic was progressively elevated. When the samples started sliding across the friction surfaces, the screw gradually lifted them. A ruler was used to measure the horizontal and vertical height values, and the coefficient of static friction was specified by using the tangent of that angle according to Fadavi *et al*. (2013) as follows:

$$\mu_s = \tan\theta \quad (12)$$

Where μ_s is the coefficient of static friction, θ is the angle between the horizontal surface and the inclined surface at which samples just start to slide down.

Data analysis:

For descriptive statistics, data were analyzed by spreadsheet software (Microsoft EXCEL version 2016) and SPSS (statistical program for the social science, Chicago, IL, version 24). On the properties, a comparison of means and standard deviation (SD) was performed for two maize varieties.

RESULTS AND DISCUSSION

A summary of the physical and mechanical characteristics of two maize varieties are presented in (Tables 1 to 3) for the dimensional, gravimetric and frictional characteristics respectively under 11% moisture content (MC).

Table 1. Physical properties of Hi-Tech and Hybrid 168 maize grain varieties under 11 % MC.

Parameter	Hi-Tech (White)				Hybrid 168 (Yellow)			
	Min.	Max.	Mean	SD.	Min.	Max.	Mean	SD.
Length, mm	7.66	11.95	10.63	1.05	9.14	11.58	10.02	0.62
Width, mm	8.77	11.07	10.00	0.67	6.80	9.29	8.29	0.65
Thickness, mm	3.91	8.82	5.28	0.44	3.52	7.25	4.81	1.03
Surface area, mm^2	168.27	265.70	211.84	27.05	139.03	225.05	169.07	22.05
Projected area, mm^2	53.42	101.98	83.75	11.64	50.42	82.95	65.36	7.57
Volume, mm^3	205.25	407.26	291.60	55.99	154.15	317.45	207.96	41.40
Arithmetic diameter, mm	7.80	9.60	8.64	0.47	7.12	8.52	7.71	0.38
Geometric diameter, mm	7.32	9.20	8.20	0.52	6.65	8.46	7.32	0.47
Sphericity, %	65.95	110.11	77.77	9.02	63.74	89.47	73.37	6.98
Aspect ratio, %	78.17	115.93	94.77	9.10	72.03	94.95	82.93	6.86

Table 2. Frequency distribution of Hi-Tech and Hybrid 168 maize grain varieties

Dimensional	Frequency	Hi-Tech (White)	Hybrid 168 (Yellow)
		%	%
	≤ 8 mm	5	0
Length	> 8-10 mm	20	60
	> 10 mm	75	40
	≤ 9 mm	10	85
Width	> 9-10 mm	40	15
	> 10 mm	50	0
	≤ 4.5 mm	30	50
Thickness	> 4.5-6 mm	60	35
	> 6 mm	10	15

Table 3. Gravimetric properties of "V1" and "V2" varieties

Parameter	Hi-Tech (White)				Hybrid 168 (Yellow)			
	Min.	Max.	Mean	SD.	Min.	Max.	Mean	SD.
Unit mass (M_1), g	0.26	0.44	0.35	0.05	0.18	0.38	0.25	0.05
Mass of 100 (M_{100}), g	32.5	35.5	33.6	11. 94	21	22.5	21.6	5.48
Bulk density (ρ_b), g/cm^3	0.792	1.020	0.850	0.075	0.667	0.900	0.775	0.059
True density (ρ_s), g/cm^3	1.25	1.93	1.42	0.197	1.05	1.50	1.28	0.115
Porosity (ε), %	33.33	47.20	39.89	3.58	36.00	41.67	39.12	1.85

Physical properties of Hi-Tech"V1" and Hybrid 168"V2" maize varieties Size

:The mean "V1" length, width, and thickness were found to be 10.63 $^{\pm 1.05}$ mm, 10.00 $^{\pm 0.67}$ mm, and 5.28 $^{\pm 0.44}$ mm, respectively as shown in (Table 1 and 2). But the "V2" length, width, and thickness recorded 10.02 $^{\pm 0.62}$ mm, 8.29 $^{\pm 0.65}$ mm, and 4.81 $^{\pm 1.03}$ mm, respectively as shown in (Table 1 and 2). There is a similarity between these results and the studies of Daboul *et al*. (2011) for two classes of maize (single hybrid (10) and (162)), and El Fawal *et al*. (2009) for two varieties of maize (hyb.310) and (hyb.352).

Surface area, projected area, and volume:

The mean "V1" maize variety surface area was found about 1.25 times of "V2". The larger dimensions of the "V1" are the reason for the higher values surface area of Hi-Tech than that "V2". The mean surface areas of "V1" and "V2" varieties were 211.84 $^{\pm 27.05}$ and 169.07 $^{\pm 22.05}$ mm^2, respectively as shown in Table 1. As the results, the mean projected areas of "V1" and "V2" varieties were 83.75 $^{\pm 11.64}$ and 65.36 $^{\pm 7.57}$ mm^2, respectively. The grain volumes of V1 and V2 varieties varied between 291.60 $^{\pm 55.99}$ and 207.96 $^{\pm 41.40}$ mm^3, respectively.

The arithmetic diameter and geometric diameter:

In the "V1" maize variety, the arithmetic diameter and geometric diameter were 8.64 $^{\pm 0.47}$ mm and 8.20 $^{\pm 0.52}$ mm, respectively. The sphericity and aspect ratio were 77.77 $^{\pm 9.02}$ % and 94.77 $^{\pm 9.10}$ %, respectively as shown in Table 1. While "V2" variety, the arithmetic diameter and geometric diameter 7.71 $^{\pm 0.38}$ mm and 7.32 $^{\pm 0.47}$ mm, respectively. The sphericity and aspect ratio were 73.37 $^{\pm 6.98}$ % and 82.93 $^{\pm 6.86}$ %, respectively.

Mass:

The mean mass of one hundred maize grains of "V1" and "V2" varieties were found to be 33.6 – 21.6 g, respectively as shown in Table 3 and 4. One-point worthy of note however that is the one hundred grain weight is a function of the single mass of the maize grains.

True density, Bulk density and Porosity:

The average true and bulk densities for "V1" and "V2" varieties were found to be true density 1.42 and 1.28 g/cm^3 and bulk density 0.850 and 0.775 g/cm^3, respectively as shown in Table 3 while the porosity was computed from the values of the true and bulk densities using equation (10) as 39.89 and 39.12 %. The true density of the maize grains showed that the grains are slightly less dense than water and therefore will float on water.

Table 4. Frequency distribution for one grain of "V1" and "V2" varieties mass

Dimensional Frequency		Hi-Tech (White)	Hybrid168 (Yellow)
		%	%
Mass (M)	≤ 0.3 g	20	90
	> 0.3-0.4 g	60	10
	> 0.4 g	20	0

Mechanical properties

Angle of repose

The mean angle of repose (α) of "V1" and "V2" varieties was found to be 24.59 ° $^{\pm 2.47}$ and 25.90 ° $^{\pm 4.47}$, respectively as shown in Table 5.

Table 5. Mechanical properties of "V1" and "V2" maize varieties

Parameter		"V1" Min.	Max.	Mean	SD.	"V2" Min.	Max.	Mean	SD.
The angle of repose (α), °		20.11	28.61	24.59	2.47	20.65	32.62	25.90	4.47
Static of coefficient friction (μ_s)	Wood	0.39	0.56	0.44	0.07	0.42	0.56	0.48	0.05
	Plastic	0.33	0.40	0.36	0.06	0.32	0.49	0.38	0.06
	Steel	0.13	0.27	0.20	0.05	0.21	0.30	0.24	0.03
	Glass	0.23	0.38	0.30	0.04	0.30	0.36	0.34	0.02

Coefficient of static friction :

(μ_s) for "V1" and "V2" varieties against four different surfaces wood, plastic, steel, and glass were found to be (0.44 - 0.48), (0.36 - 0.38), (0.20 - 0.24) and (0.30 - 0.34), respectively, in that order as shown in Table 5 and Fig. 3.

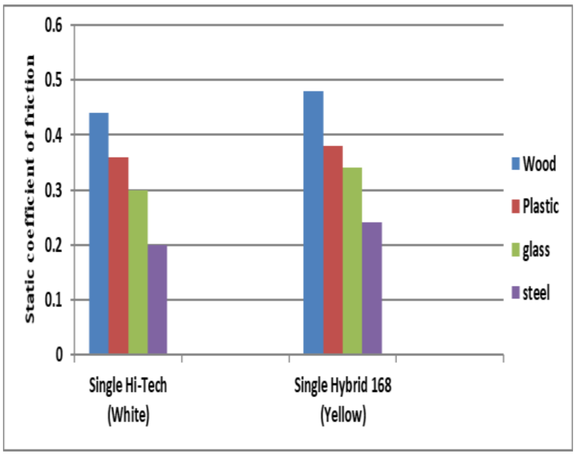

Fig. 3. Coefficient of static friction for "V1" and "V2" varieties on four different surfaces.

It would be observed that the coefficient of static friction was highest on wood and lowest on the steel. Also, it was observed that the smoother of structural surface, the lower recorded coefficient of static friction on the surface. These findings are comparable to those of the investigations of Daboul *et al*. (2011) for two classes of maize single hybrid 10 and 162.

CONCLUSION

The physical and mechanical parameters of maize grain variations discovered provided a database for developing maize planter machines as follows: The hopper, feeding mechanisms, and grain tube are all determined by the size of the maize grains. The hopper slope is determined by the repose angle to allow free flow of the grains. The machine hopper's manufacturing material is determined by the static coefficient of friction. The designing machine should be used in the following circumstances: the hopper slope angle should be around 30°, and the hopper should be made of steel.

ACKNOWLEDGMENT

The authors thank Dr Mohamed Fayed for his helpful and thanks their family members.

REFERENCES

Al-Mitewty, M. I., A. Yahya, M. Razif, and N. Mat. 2019. Physical and mechanical properties of sweet corn plant. Agricultural Engineering International: CIGR Journal, 21(4): 152–160.

Altuntas, E. and Erkol, M., 2010. Physical properties of shelled and grain walnuts as affected by the moisture content. Czech J. of Food Sci. 28(6): 547-556. https://doi.org/10.17221/194/2008-CJFS.

Daboul, A. K., El Awady, M. N., Hamada, M. A., EL Attar, M. Z., 2011. Physical and mechanical characteristics of corn kernels. Misr J. Agric. Eng. 28(4): 961 - 974. https://doi:10.21608/mjae.2011.102606.

Davies, R. M., 2009. Some physical properties of groundnut grains. Res. J. of Applied Sci., Eng., and Technol. 1(2):10-13.

El Fawal, Y. A., Tawfik, M. A., El Shal, A. M., 2009. Study on physical and engineering properties for grains of some field crops. Misr J. Agric. Eng., 26(4):1933-1951.https://doi:10.21608/mjae.2009.107579.

Fadavi, A., Hassan-Beygi, S. R. and Karimi, F., 2013. Moisture dependent physical and mechanical properties of Syrjan region wild pistachio nut. Agric. Eng. Int.: CIGR Journal,15(2):221-230. http://www.cigrjournal.org/index...

FAO, 2018. Production crops All Data. FAOSTAT; FAO: Rome, Italy.

Goyal, R. K., Kingsly, A. R. P., Kumar, P. and Walia, H., 2007. Physical and mechanical properties of aonla fruits. J. of Food Eng. 82:595-599. https://doi.org/10.1016/j.jfoodeng.2007.03.019.

Ismail Z.E. 2015. Seeder equipped with seeds delivery mechanism depending on an oscillating motivation unit. Misr Journal of Agricultural Engineering 32(4): 1761-1774.

Kruszelnicka,W. 2021. Study of selected physical-mechanical properties of corn grains important from the point of view of mechanical processing systems designing. Materials, 14, 1467. https://doi.org/10.3390/ma14061467.

Ministry of Agriculture-Egypt, 2021. http://agr-egypt.gov.eg/.

Perez, E.E., Crapiste, G.H. and Carelli, A.A., 2007. Some physical and morphological properties of wild sunflower seeds. Biosystems Eng. 96(1): 41-45. https://doi.org/10.1016/j.biosystemseng.2006.09.004.

Seifi, M. R. and Alimardani, R., 2010. The moisture content effect of some physical and mechanical properties of corn. J. Agric. Sci., Canadian Centre of Sci. and Edu. 2(4):125-134.

Soyoye, B. O., O. C. Ademosun, and L. A. S. Agbetoye. 2018. Determination of some physical and mechanical properties of soybean and maize in relation to planter design. Agricultural Engineering International: CIGR Journal, 20(1): 81–89.

Vursavus, K. and Ozguven, F., 2004. Mechanical behaviour of apricot pit under compression loading. J. of Food Eng. 65:255-261. https://doi.org/10.1016/j.jfoodeng.2004.01.022.

Yildirim, S. and Tarhan, S., 2016. Aerodynamic properties of apricot pits. J. Agric. Fac. of Gaziosmanpasa Univ. 33 (1): 47-55.

تقدير بعض الخصائص الفيزيائية والميكانيكية لحبوب الذرة

ريم حسانين محمد هناوه [١]، أحمد محمد سعد الدين الشال [١] وعمر عبد اللطيف عمر عبد الوهاب[٢]

[١]قسم الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق.

[٢]معهد بحوث الهندسة الزراعية – الدقي – الجيزة.

للذرة أهمية كبيرة بالنسبة للإنسان والماشية والدواجن من حيث استخدامها كعلف أو في صناعة الأعلاف الجافة. تعتبر الخصائص الفيزيائية والميكانيكية لحبوب الذرة مهمة لتصميم آلات الزراعة (قادوس البذور، جهاز التلقيم، أنابيب البذور) آلات تدريج الحبوب، أماكن التخزين ومكونات آلات التخزين .لذا كان الهدف من هذه الدراسة تحديد الخصائص الفيزيائية والميكانيكية لأنواع معينة من الذرة وهي الذرة (هاي تك فردي أبيض ، هجين فردي أصفر ١٦٨) . تم اختيار ١٠٠ حبة ذرة عشوائيا من صنفي الذرة (هاي تك فردي أبيض، هجين فردي أصفر ١٦٨) وجد أن متوسط المحتوي الرطوبي ١١% لكل من الصنفين. النتائج التي تم التوصل إليها لصنفي الذرة هاي تك، هجين ١٦٨ متوسط الطول والعرض والسمك ومساحة السطح ومساحة الإسقاط وأحجام البذور والقطر الحسابي والقطر الهندسي والمسامية ونسبة الأبعاد (١٠,٦٣- ١٠,٠٢ مم)، (١٠,٠٠- ٨,٢٩ مم)، (٥,٢٨-٤,٨١ مم)، (٢١١,٨٤-١٦٩,٠٧ مم٢)، (٨٣,٧٥-٦٥,٣٦ مم٢)، (٢٩١,٦-٢٠٧,٩٦ مم٣)،(٨,٦٤-٧,٧١ مم)،(٨,٢٠-٧,٣٢ مم) ،(٧٧,٧٧-٧٣,٣٧%(،(٩٤,٧٧-٨٢,٩٣%) علي الترتيب. كانت الكثافة الحقيقية والظاهرية والمسامية (١,٤٢-١,٢٨) جم/سم٣، (٠,٨٥٠- ٠,٧٧٥) جم/سم٣، (٣٩,٨٩- ٣٩,١٢) % لأصناف الذرة هاي تك وهجين ١٦٨ على الترتيب. وجد أن متوسط زاوية التكويم تبلغ ٥٢٤,٥٩ و٥٢٥,٩٠ لأصناف الذرة هاي تك وهجين ١٦٨ على الترتيب. تم حساب متوسط معاملات الاحتكاك لحبوب الذرة من الصنفين هاي تك وهجين ١٦٨ على أربعة أسطح مختلفة (الخشب ،البلاستيك، الصلب، الزجاج) كانت (٠,٤٤-٠,٤٨)، (٠,٣٦-٠,٣٨)، (٠,٢٠-٠,٢٤)، (٠,٣٠-٠,٣٤) على الترتيب.