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Identifying Some Physical, Chemical, And Mechanical Properties Of Seeds Of Some Maize (*Zea Mays* L.) Genotypes.

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ABSTRACT

Maize (*Zea mays*. L) is an economically important cereal crop often used as a food and feed product necessary for human health and animals, as well as raw material for producing high quality protein and carbohydrate products. The ANOVA result showed significant difference at ($p < 0.05$), and Duncan's mean results also showed statistically significant differences among the ten genotypes. Some of chemical traits determined and mean values of these properties were recorded such as Moisture (7.747 % to 8.52%), ash (1.51to 1.667%), protein (9.68 to 12.44%), oil (2.853 % to 4.283 %) and carbohydrate (73.953 % to 78.357%) with some of physical and mechanical properties determined include thousand kernel weight (205.582 to 285.680 g), bulk density (0.718 to 0.783 $g.ml^{-1}$), true density (1.255 to 1.310 $g.ml^{-1}$), hydration index (0.447 to 0.484), swelling index (0.351 to 0.783), porosity (37.523 to 43.864 %) size [(length 9.080 to11.860 mm), width (6.724 to 8.780 mm) and thickness (4.170 to 5.745 mm)], geometric mean diameter (6.543 to 8.371 mm), sphericity (0.644 to 0.754 %), roundness (0.564 to 0.724) ,surface area (134.426 to 219.978 mm^2) and volume(148.551 to 244.598 mm^3), by using ten different maize varieties in this study, which these properties of maize seeds are important to design the planter/seeder (hopper, metric device, tube), grading machines and to select members and storage equipment. This experiment was performed in the laboratory of the biotechnology and crop science department.

***Keywords*:** maize genotypes, chemical components, physical properties, geometric mean diameters and mechanical properties

INTRODUCTION

Maize (*Zea mays* L.) ranks as the third most important food crop after rice and wheat and serves as an excellent source of carbohydrates, proteins, fats, and various essential vitamins and minerals. Because it is cheaper compared to wheat and rice, it is widely utilized as a staple food across the globe. [1]. It is widely used for human nutrition, animal and poultry feed, accounting for up to 70% of the dry feed industry, 20% of bread components, and interference in certain industries such as oil, glucose, and fructose. The chemical composition of the corn consists of about 70% carbohydrates, 10% proteins, 4% oil, 2.3%, crude fiber, 1.4% ash, and10.4% albumen. [2] and [3]. Maize, is usually known as corn and it is belonging of the Poaceae family of grasses. It is one of the cereal crops that are most commonly grown throughout all ecological zones and may be grown with success in a variety of soil types, from clay loam soil to loamy sand soil [4]. Based on the type of endosperm, maize genotypes are grouped into several types such as; dent, flint, floury, waxy, amylase, ear and sweet corn. In most parts of the world, maize has been recognised as one of the most important cereal crops, and it is used for food, feed, and industrial purposes. Due to its high genetic production value among all cereal crops, it is known as the "Queen of Cereals" due to its high potential genetic value among all cereal crops [5]. The total area of corn planted worldwide is about 139 million hectares, producing 598 million metric tons. The United States is the largest producer and exporter of corn in the world, with about 240 million metric tons of cropped area of 1 million hectares. Among all cereal crops, maize ranks fifth in area, fourth in production and third in yield [6]. In many aspects related to the design of machinery equipment during agricultural process, such as handling, planting, harvesting, threshing, cleaning, sorting, and drying for maximum efficiency and highest quality of the finished product, knowledge of the physical properties of maize, like other agricultural materials, is necessary [7] and [8]. For instance, when creating machines for cleaning, grading, sorting, and packing, it is important to know factors such as size, shape, geometric mean diameter, and sphericity. Additionally, surface area and porosity are crucial for assessing the heat transfer rate during heating and drying processes, which informs the design of heat exchangers and dryers. The knowledge of some physical and mechanical properties of these seeds is an important tool for designing agricultural machines and equipment for planting, harvesting, processing, packaging and storage. Moreover, bulk density, true density, and porosity are vital for the design of aeration, storage, transportation, and separation systems. These density properties are also utilized to determine the dielectric traits of cereal grains [2]. Thus, the physical property information is relevant to engineers and food scientists, processors, and other scientists who might use these resources. [7] and [8].

Hence, the objective of this study was to provide information on chemical composition and information on physical properties of some local and foreign maize genotypes and correlation these traits to the design and manufacture of agricultural equipment.

Material and method

A-Selection of the genotypes

This research was done in year 2024 in the laboratory on ten genotypes of maize seeds (Sara, Al-Maha, Fajr-1, Baghdad-3, ZP.434*A, ZP.434*B, MSI*B, Dhqan, Corpeto and Dracma) which were obtained from harvested seeds in Qlyasan research station affiliated to College of Agriculture (Lat. 35o 34 307; N, Long. 45o 21 992; E, 765 m.a.s.l.), University of Sulaimani. These seeds are cleaned manually to remove impurities such as dust, stone, immature and damaged kernels. Then the seeds were placed in sealed bags and kept in the refrigerator until the required tests were performed.

B-Determination of chemical properties of maize seeds:

The chemical properties of ten genotypes of corn seeds which were previously mentioned, were determined in the laboratory and included:

1-Determination of moisture %

To get the moisture content percentage. The following formula was used [9];

moisture content % $= \frac{(W1-W2)}{W1-W}$ × 100 ……………….(1)

where;

W1= Weight of the dish with the material before drying in gram

W2= Weight of the dish with the material after drying in gram

W= Weight of the empty dish in gram

2-Determination of ash content %

To get the ash content percentage, the following formula was used [9];

protein content % $= \frac{(W2-W)}{W1-W}$ × 100………………………(2)

where;

W2 = Weight of the dish with the ash in gram

W = Weight of empty dish in gram

W1 = Weight of the dish with the dried material taken for test in gram

3-Determination of crude protein content %

The Micro Kjeldahl method, as described by [9], was used to evaluate the protein content of the seed maize.

4-Determination of Crude oil content %

Crude fat was estimated by using soxhlet extraction apparatus standard method described by [9].

oil content % $= \frac{(W2-W1)}{W3}$ × 100 ………………(3)

Where;

W1 = weight of the empty extraction flask

W2 = weight of the flask and oil extracted

W3 = weight of the sample

5-Carbohydrate %

This was calculated by deducting the previously mentioned parameters' values from 100, (i.e. by difference method) [9].

carbohydrate %= 100 - (moisture %+ ash%+ protein% + oil %) ………….(4)

C-Determination of physical (Gravimetric) properties of maize seeds

1-Thousand Kernel Weight (gm)

One thousand (1000) seeds were randomly selected from each sample and weighed using a digital balance with a sensitivity of 0.001 g as suggested by [10].

2-Bulk density

Bulk density is defined as the mass per unit volume of a seed including pore space. It is calculated as the ratio of the mass of the sample to its total volume as shown by [10], and expressed as g/ml.

$Bulk\ density = \frac{weight\ of\ sample\ (gm)}{volume\ occupied\ by\ sample\ (mm^3)}$……………….(5)

3-True density

The average true density was expressed as a ratio, weight of 10 grams from samples' seeds to the volume of toluene displaced, which was determined by using the toluene displacement method. The amount of toluene ($C7H8$) that have been pushed out was found by immersing a weighed quantity of maize seeds
samples in the toluene [11]

$$True\ density\ \left(\frac{\text{g}}{\text{mm}^3}\right) = \frac{weight\ of\ sample\ (gm)}{volume\ of\ toluene\ displaced\ (mm^3)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

4-Porosity

the relationship between true density and bulk density is known as porosity, and it was calculated as described by [12] by the following equation;

$$Porosity = \left(1 - \frac{Bulk\ density}{True\ density}\right) \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

5-Hydration Capacity and Hydration Index

Ten-gram seeds were weighed and then placed in a measurement cylinder. After adding 50 cc of water to this, the cylinder was wrapped in aluminum foil and let sit at room temperature for the entire night. After draining the seeds and using filter paper to remove extra water, the enlarged seeds were weighed again [13]. Hydration capacity and hydration index were calculated using the following formula;

$$Hydration\ capacity\ (\%) = \frac{Weight\ after\ soaking - Weight\ before\ soaking}{weight\ of\ seeds} \times 100 \ldots\ldots\ldots\ldots (8)$$

$$Hydration\ capacity\ (per\ seed) = \frac{Weight\ after\ soaking - weight\ before\ soaking}{Number\ of\ seeds} \ldots\ldots\ldots\ldots (9)$$

$$Hydration\ Index = \frac{Hydration\ capacity\ per\ seed}{Weight\ of\ one\ seed} \ldots\ldots\ldots\ldots (10)$$

6-Swelling capacity and swelling index

Ten-gram seeds were weighed, moved to a measurement cylinder, and their volume was noted. This was filled with 50 milliliters of water, covered with aluminum foil, and let to sit at room temperature for the entire night. After draining the water, the amount of soaked seeds was measured in a graduated cylinder. [13]. Swelling capacity and swelling index was calculated using the following formula:

$$Swelling\ capacity\ (\%) = \frac{Volume\ after\ soaking - Volume\ before\ soaking}{weight\ of\ seeds} \times 100 \ldots\ldots\ldots (11)$$

$$Swelling\ capacity\ (per\ seed) = \frac{Volume\ after\ soaking - Volume\ before\ soaking}{Number\ of\ seeds} \ldots\ldots\ldots (12)$$

$$Swelling\ Index = \frac{Swelling\ capacity\ per\ seed}{seed\ Volume\ (ml)} \ldots\ldots\ldots\ldots (13)$$

D- Determination of geometric and mechanical properties of maize seeds

1-Geometric mean diameter "*Dg*"

The seed's three axial dimensions called length "L, in mm", width "W, in mm" and thickness "T, in mm" were measured for 30 randomly chosen seeds using a manual Vernier-caliper with an accuracy of 0.02 mm. As described by [14], the geometric mean diameter was determined using the Equation:

$$Dg(LWT)^{1/3} \ldots\ldots\ldots\ldots\ldots (14)$$

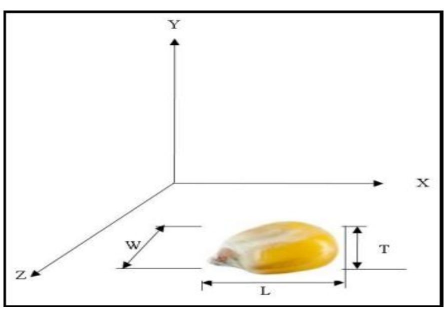

Figure 1. properties dimensions the of maize Figure 2. Vernier caliper-a device for calculating physical properties of maize seed

2-Arithmetic diameter "*Da*"

As described by [14], the Arithmetic mean diameter was determined using the Equation;

$$Da = \frac{L+W+T}{3} \ldots\ldots\ldots\ldots (15)$$

3-Sphericity "*S*"

This is determined by using the equation as shown by [15];

$$S = \frac{(LWT)^{1/3}}{L} \times \ldots\ldots\ldots\ldots (16)$$

4-Roundness

The roundness of the materials was determined as described by ([16] by using Equation;

$$Roundness = [(W/L + (T/L) + (T/W)]/3 \ldots\ldots\ldots\ldots\ldots\ldots (17)$$

5-surface area "*mm*^{2}"

Surface area (Sa) is calculated according to [17] as follows:

$Sa = \pi \cdot (Dg)^2$…………….…….(18)

6-Volume "mm^3"

Volume is specified as the procedure of [18] as follow:

$V = \frac{\pi}{6} L \cdot W \cdot T$……………….(19)

Statistical Analysis

The statistical analysis was subjected to a one-way analysis of variance (ANOVA), and significant differences were analyzed using Duncan's multiple range tests (P≤0.05). The statistical software XLSTAT, version (2019.2.2.59614) was used for the data analysis and standard deviations were reported.

Result and discussion

Chemical components

The chemical components for ten maize genotypes were analyzed in this research and these components include the following:

1. **Moisture content %**

The moisture content of ten maize genotypes was found to range between 7.747 %-8.52 % as shown in Figure (3). It is evident that Dhqan recorded lower value and Al Maha recorded the highest value. Based on previous research, this percentage of moisture content is low as which that mentioned in all maize genotypes, this is due to the delay in harvesting, which sometimes may be harmful to the seeds, especially during the storage stage, i.e. it may lead to burning of the grains during their handling in the silo, this means that if seeds moisture content of less than 9˚C will sometimes lead to burning of the seeds due to the constant friction of the seeds during their continuous movement during handling.

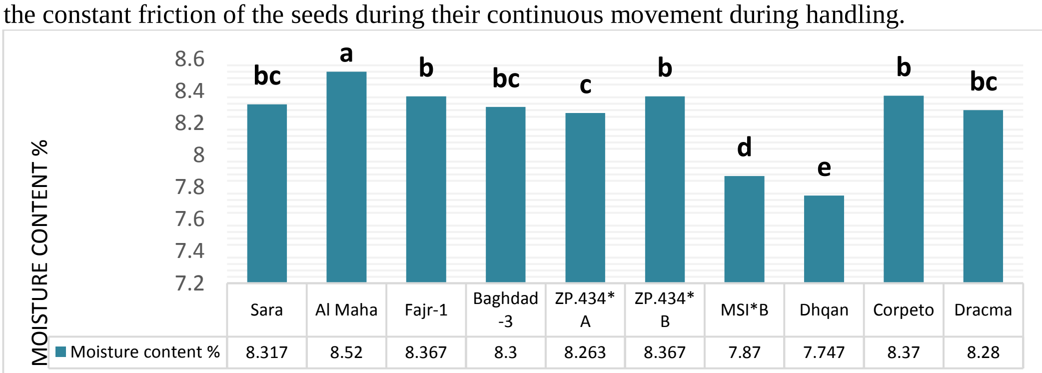

Figure 3. Graphical representation of moisture content of different maize varieties.

2.Ash content %

Different corn genotypes' ash content is shown in Figure (4). the Fajr-1 variety recorded maximum value of 1.667 % but the Baghdad genotype recorded minimum value which was 1.51 %. While the rest genotypes recorded the same values closely. The seeds with a higher ash content refer to a higher percentage of non-endosperm material. Ash values are measured to indicate the presence of non-sweed components are present, and to indicate the level or percentage of minerals present in samples of maize or other cereal crops [19]. These results agree with [20], who reported similar results in different hybrids of maize.

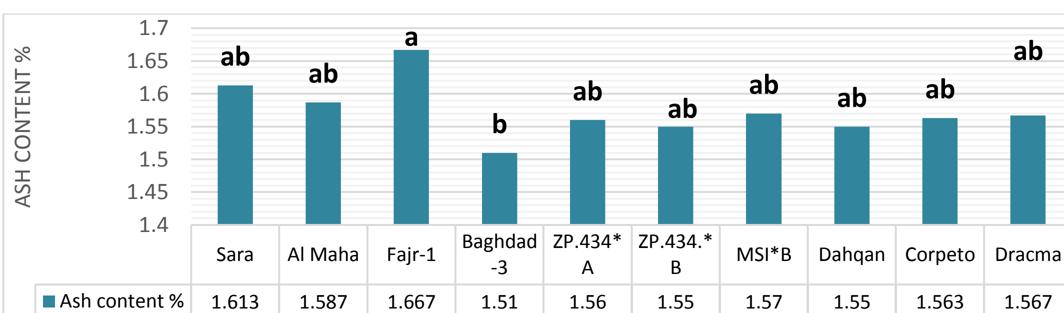

Figure 4. Graphical representation of ash content of different maize varieties.

3.protein content %

The second largest chemical component of cereal is protein, the proximate analyses showed in Figure (5), that protein content ranged from 9.68% to 12.44% which was recorded for Sara and Corpeto genotypes respectively. The findings of the study are in agreement with the results reported by [19], and also the same result is consistent with studies by [21] irrespective of the maize genotype.

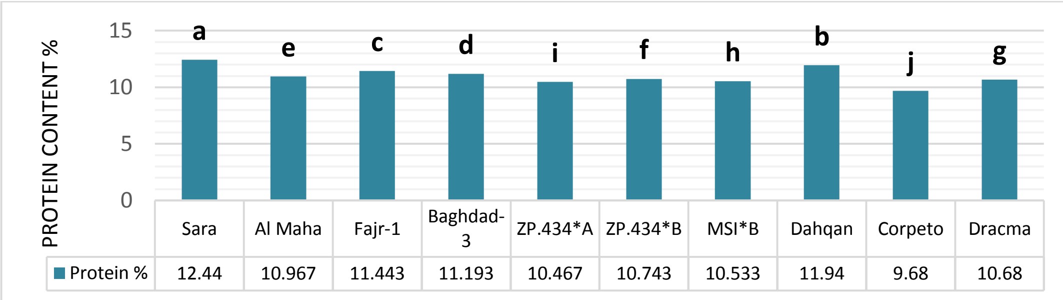

Figure 5. Graphical representation of protein content of different maize varieties.

4.Oil content %

According to the result shown in Figure (6), the oil content is ringing between 2.853 % to 4.283 %, which the maximum value recorded by the Baghdad-3 genotype and the minimum value recorded by the Corpeto genotype. In general, maize seeds contain about 1.2 - 5% oil, and seed size has significant effective on the grain contents of oil that noted by [22]. Results appears are similar to the results of [23] and [24].

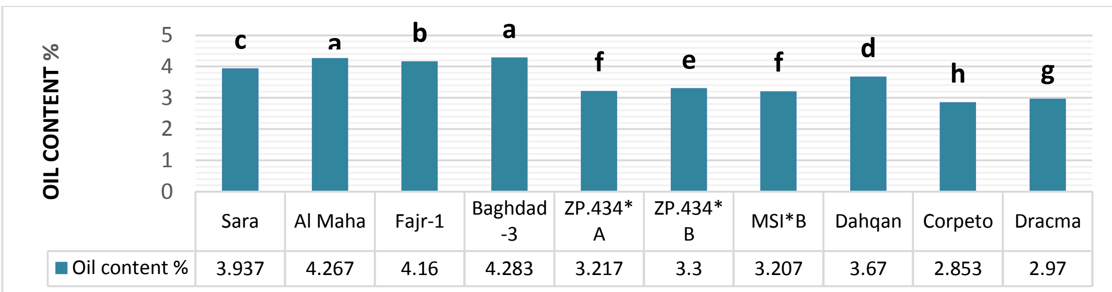

Figure 6. Graphical representation of oil content of different maize varieties.

5.Carbohydrate content %

The carbohydrate content of different corn genotypes which used in this research was analyzed and shown in Figure (7). The average means of carbohydrate content observed for all genotypes ranged from 73.953 % to 78.357 % and showed significant differences at (P≤0.05), It's clear that the Sara genotype recorded the lowest value as 73.953% while the Corpeto genotype recorded highest value at 78.357%. These outcomes results are similar to those that were obtained by [19] and [25] with notable variations present between all the genotypes. maize is the main source of carbohydrates which is the most abundant component in their seeds and it is very important due to its use as a staple food in many regions of the world [26].

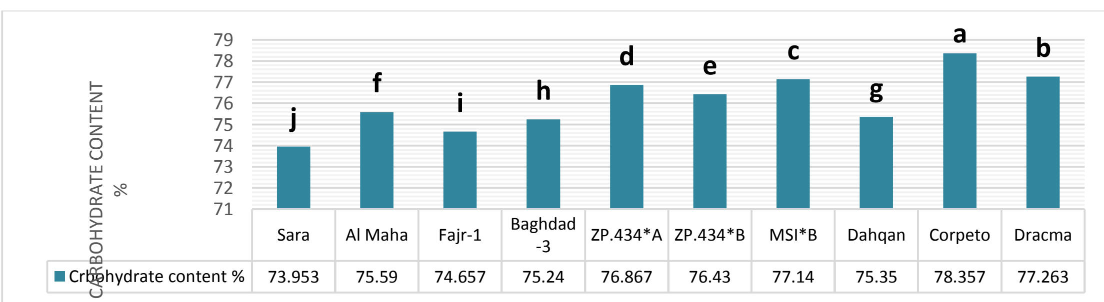

Figure 7. Graphical representation of carbohydrate content of different maize varieties.

Physical (Gravimetric) properties of maize seeds

The physical properties of maize seeds are shown in Table (1), there are significant between all genotypes of maize seeds. The weight of a thousand grains varies between genotypes and rang between 205.582 to 285.680 g with a higher value recorded by the Corpeto genotype and a lower value recorded by the Dracma genotype. Variation in the test weight of different maize genotypes was observed due to different sizes of maize seed and moisture content [27]. The bulk density of selected maize genotypes ranged between 0.783- 0.718 g.ml^{-1}, the maximum value recorded by the Al Maha genotype and the minimum value recorded by the Corpeto genotype. Variations of true density are shown in Table (1), and it is range from 1.310 to 1.255 g.ml^{-1}, with the high value recorded for the Dhqan genotype while the low value recorded to Sara, Al Maha, Fajr-1 and Baghdad-3, while for other genotypes become between the of them. Because of values of all genotypes are more than 1, therefore the seeds will sink in the water and these results agree with [28]. The true density of most maize seeds increases with the increase in the moisture content of the seeds, i.e. there is a direct relationship between them, and this feature was primarily due to the greater increase in grain volume compared to their masses [2]. The porosity of maize seeds ranged from 37.523 to 43.864 %, with the highest value recorded for Corpeto genotype and while lowest value to the Al Maha genotype. Porosity depends upon the bulk density and true density. According to these results, seed bed with high porosity will have low resistance to water vapor escape during the drying process, which may lead to lower power to drive the aeration fans during storage of seeds [8]. According to the results shown in table (1), there are significant differences between the genotypes in the research.

Table 1: Physical (Gravimetric) properties of ten maize genotypes

Genotypes	Thousand Kernel Weight (gm)	Bulk density g.ml^{-1}	True density g.ml^{-1}	hydration index	swelling index	Porosity %
Sara	264.916^{b}	0.769^{b}	1.255^{c}	0.436^{f}	0.783^{a}	38.627^{i}
Al-Maha	253.195^{c}	0.783^{a}	1.256^{c}	0.458^{cd}	0.421^{c}	37.523^{j}
Fajr-1	237.016^{f}	0.748^{d}	1.255^{c}	0.484^{a}	0.394^{d}	40.207^{h}
Baghdad	240.904^{d}	0.739^{e}	1.256^{c}	0.453d^{e}	0.376^{e}	41.118^{g}
ZP. 434*A	240.607^{d}	0.737^{f}	1.277^{bc}	0.480^{a}	0.351^{f}	42.281^{e}
ZP.434*B	222.556^{g}	0.751^{c}	1.279^{bc}	0.464b^{c}	0.395^{d}	41.240^{f}
MSI*B	240.017^{e}	0.725^{h}	1.280^{bc}	0.447^{e}	0.375^{e}	43.227^{c}
Dhqan	210.679^{h}	0.722^{i}	1.310^{a}	0.467^{b}	0.378^{e}	43.595^{b}
Corpeto	285.680^{a}	0.718^{j}	1.282^{bc}	0.469^{b}	0.401^{d}	43.864^{a}
Dracma	205.582^{i}	0.735^{g}	1.297^{ab}	0.470^{b}	0.431^{b}	42.576^{d}

The hydration index ranged between 0.447 to 0.484, with the maximum value recorded by the Fajr-1 genotype but minimum value recorded by the MSI*B genotype and the other varieties recorded values closely to them, the results were more those that got by [13] which they work on it, but swelling index observed in present study which ranged between 0.351 to 0.783, the higher value observed by Sara genotype and the lower value by the ZP.434*A genotype, was similar to the results observed by [29] and [30].

Geometric and mechanical properties of maize seeds

The results in Table (2), show the average axial dimensions of maize seeds genotypes, with length ranging from 9.080 to 11.860 mm, width from 6.724 to 8.780 mm, thicknesses from 4.170 to 5.745 mm, these for (Sara- Baghdad-3), ZP.434*A- Baghdad-3) and (Sara- ZP.434*A) respectively. The axial dimensions of the grains are affected by the moisture content as well as the fullness of the maize ear with grains at the time of maturity. Based on these parameters (length, width and thicknesses), the geometric mean diameter of maize seeds is determined to be ranged between 6.543 to 8.371 mm, that maximum value recorded by Baghdad genotype and the minimum value recorded by Sara genotype, same results are consistent with [28] and [31] whom obtained them through their study. This characteristic is necessary for determination of design of the cells average of sieves sizes for grading and cleaning of seeds and helps in the design of hopper [32]. The value of sphericity of maize seeds varied from 0.644 to 0.754 %, which higher value recorded by Corpeto and lower value recorded by Al-Maha genotype, and all genotypes tends to be more sphericity, the same results can be observed in the results of [2]

Table 2: Geometric and mechanical properties of maize genotypes

genotypes	Axial dimension (mm) Length mm	Width mm	Thickness mm	Geometric dimension mm	Sphericity %	roundness	Surface area mm^2	Volume mm^3
Sara	9.080^{j}	7.393^{d}	4.170^{j}	6.543^{j}	0.696^{g}	0.615^{f}	134.426^{j}	146.551^{j}
Al-Maha	10.533^{c}	6.935^{h}	4.327^{i}	6.802^{i}	0.644^{i}	0.564^{h}	145.236^{i}	164.592^{i}
Fajr-1	10.884^{b}	7.154^{f}	4.620^{h}	7.106^{g}	0.652^{h}	0.576^{g}	158.555^{g}	187.672^{g}
Baghdad-3	11.860^{a}	8.780^{a}	5.640^{c}	8.371^{a}	0.705^{e}	0.616^{f}	219.978^{a}	206.702^{b}
ZP.434*A	9.513^{i}	6.724^{i}	5.745^{a}	7.161^{e}	0.752^{b}	0.724^{a}	181.366^{c}	192.028^{e}
ZP.434*B	9.713^{g}	6.726^{i}	4.906^{g}	6.842^{h}	0.702^{f}	0.643^{e}	146.992^{h}	167.507^{h}
MSI*B	10.058^{e}	7.026^{g}	5.126^{e}	7.127^{f}	0.706^{e}	$0.646d^{e}$	159.493^{f}	189.399^{f}
Dhqan	9.884^{f}	7.534^{c}	5.033^{f}	7.207^{c}	0.728^{d}	0.648^{d}	163.094^{d}	195.792^{c}
Corpeto	10.273^{d}	8.015^{b}	5.684^{b}	7.762^{b}	0.754^{a}	0.687^{b}	189.180^{b}	244.598^{a}
Dracma	9.584^{h}	7.213^{e}	5.328^{d}	7.167^{d}	0.747^{c}	0.679^{c}	161.288^{e}	192.601^{d}

The sphericity value approaching unity exhibits the uniformity of grain shape. There were differences in roundness mean values of maize seeds due to differences in genotypes (Table 2), which ranged between 0.564 to 0.724, with the maximum value recorded to ZP.434*A and the minimum value recorded to Al Maha. according to these two properties, the cell in seed metering plates of a planter is critical for accurately dispensing seeds. The design can be circular, semi-circular, or slant type, and the characteristic dimensions of these cells should be tailored to match the planted seeds. Specifically, the dimensions of the cells must be equal to or greater than the major, intermediate, and mean diameters of the seeds. This ensures that the seeds fit properly within the cells and are metered out efficiently during planting, minimizing the risk of clogging or seed damage while maximizing precision in seed placement [27]. The surface area and volume of maize genotypes increased from 134.426 to 219.978 mm^2 and from 148.551 to 244.598 mm^3 respectively, and the results agree with the results obtain by [6] and [31]. The study of the surface area and volume of kernels which are important during the modeling of grain drying, aeration, heating and cooling [8].

Conclusion

This study provided information on seeds chemical physical and mechanical properties of some maize genotypes cultivated in our region. The genotypes have content moderate moisture, a good percentage of ash, and a good percentage of protein. As for oil, it is low, and the percentage of carbohydrates is good. For the physical, geometric and mechanical propitiate, this research includes some results on physical, geometric and mechanical properties given different values on the geometric, shapes, sizes, volume, bulk and true density and surface area of different genotypes of corn used for cultivation, that sometimes given an idea on the design and calibration of the machines and equipment used before planting the crop in the field, which makes it easy through these tests, as well as information on the handling of the crop or storage and transactions related to the storage of the crop in the silo.

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التعرف على بعض خصائص الفيزيائية والكيميائية والميكانيكية لبذور بعض الطرز الجينية للذرة الشامية (*Zea mays* L.)

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الخلاصة

الذرة (Zea mays. L) وهي محصول حبوب مهم اقتصاديًا يستخدم غالبًا كمنتج غذائي وعلفي ضروري لصحة الإنسان والحيوان، وكذلك كمادة خامة لإنتاج منتجات بروتينية وكربوهيدراتية عالية الجودة. أظهرت نتائج تحليل التباين فروقًا معنوية عند ($p < 0.05$)، وكما أظهرت نتائج متوسطات دنكن أيضًا فروقًا معنوية إحصائيًا بين الأنماط الجينية العشرة. تم تحديد بعض الخصائص الكيميائية وتسجيل متوسط قيم لهذه الخصائص مثل الرطوبة (7.747٪ إلى 8.52٪) والرماد (1,51 إلى 1.667٪) والبروتين (9.68 إلى 12.44٪) والزيت (2.853٪ إلى 4.283٪) والكاربوهيدرات (73.953٪ إلى 78.357٪) مع تحديد بعض الخصائص الفيزيائية والميكانيكية بما في ذلك: وزن ألف حبة (205.582 إلى 285.680 غم)، الكثافة الظاهرية (0.718 إلى 0.783 غم.مل-1)، الكثافة الحقيقية (1.255 إلى 1.310 غم.مل-1)، مؤشر الترطيب (0.447 إلى 0.484)، مؤشر التورم (0.351 إلى 0.783)، المسامية (37.523 إلى 43.864٪)، الحجم [(الطول 9.080 إلى 11.860 ملم)، العرض (6.724 إلى 8.780 ملم) والسمك (4.170 إلى 5.745 ملم)]، متوسط قطر الهندسي (6.543 الى 8.371 ملم)، الكروية (0.644 الى 0.754 ٪)، الإستدارة(0.564 الى 0.724)، مساحة السطحية (134.426 الى 219.978 ملم2)، الحجم (148.551 الى 244.598ملم3)، حيث تم إجراء هذه التجربة باستخدام عشرة أصناف مختلفة من ذرة الشامية في هذه الدراسة، حيث تعتبر هذه الخصائص لبذور الذرة مهمة لتصميم آلة الزرع/البذر (القادوس، الجهاز المتري، الأنبوب)، آلات الفرز واختيار الأعضاء ومعدات التخزين. أجريت هذه التجربة في مختبر قسم التكنولوجيا الحيوية وعلوم المحاصيل. وأظهرت نتيجة تحليل التباين ANOVA مع وجود فروق معنوية عند مستوى ($p < 0.05$) كما أكشفت نتيجة متوسطات باستخدام دنكن أيضًا عن وجود فروق معنوية بين الأصناف العشرة.

الكلمات المفتاحية: أصناف الذرة، مكونات الكيميائية، خصائص الفيزياوية والميكانيكية، متوسط القطر الهندسي وخصائص الميكانيكية.