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MECHANICAL PROPERTIES OF CORN KERNELS

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ABSTRACT

Mechanical Properties of fresh corn kernels were obtained for the two varieties, White Dent Corn Single Hybrid 10 and Yellow Dent Corn Single Hybrid 155 at different levels of moisture contents ranged from 30.26 to 9.88 (w.b.%). The kernels mechanical properties were obtained firstly related to single kernels included modulus of elasticity, maximum compressive stress, rupture energy, rigidity force, penetration force and moisture content. Secondly the mechanical properties of corn kernels in bulk were measured and included pressure-density relationships and stress strain behavior. Data were demonstrated in tables, graphically and regression equations were developed to describe the previous mechanical properties dependence on moisture contents for each variety.

INTRODUCTION

Studying mechanical properties of corn kernels reduces mechanical damage through establishing and developing the mechanical systems of harvesting. In this regard, Zoerb and Hall, 1966 confirmed that mechanical properties such as compressive strength, modulus of elasticity, modulus of resilience and others are important engineering data needed to study size reduction and seed resistance to cracking under harvesting, handling and drying condition. They added that when basic data are known, new uses for the product and new methods of processing can be developed. Mechanical damage happened to corn kernels has a significant effect of corn allowable storage time, Ng et all. (1998) concluded that corn allowable storage time decreased as percent mechanically damaged kernels increased from 0 to 40 %.

Saul and Steele (1966), Storshine and Yang (1990) reported that high moisture content field shield corn could not be stored more than a few hours without deterioration in quality, even faster drying rates required for damaged corn to prevent spoilage between harvesting and drying.

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Similarly, Eistner (1990) reported that mechanically damaged corn has a lower market value and a lower export appeal. In the same direction, Gomez and Andrews (1971) confirmed that besides the risk of latoxin formation, damaged kernels detrimental effects on miller's products. They added that mechanical damage also decreases seed corn viability and results in lower yields. Researchers have been conducted many investigations to solve problems related to serial products through their mechanical properties.

Jindal et all (1978) conducted three types of tests to determine mechanical strength parameters of corn kernels, quasi-static compression, impact and breakage tests. Concerning quasi-static compression, corn kernels were fractured individually, when lying flat with their germ side down, under compression with a steel spherical indenter (0.63 cm in diameter) in an Instron testing instrument at loading rate of 0.5 cm /min. They used the following equation by Shelf and Mohsinen (1985) to calculate the apparent modulus of elasticity:

$$E = \frac{0.338 K^{\frac{3}{2}} F\left(-\mu^2\right)}{D^{\frac{3}{2}}} \left(\frac{1}{R_1} + \frac{1}{R_2}\right)^{\frac{1}{2}},$$

Where,

$E =$ modulus of elasticity ,

$\mu =$ poison's ratio (it is assumed to be 0.32 for corn regardless of its moisture content and variety (Mohsinen ,1970)

$K =$ a constant, 1.3531

$F =$ load in indenter

$D =$ displacement in indenter

R_1 and R_2 = radius of curvature of indenter.

Zoerb and Hall (1960) determined the basic mechanical and rheological properties of grain including corn. These properties included compressive strength, modulus of elasticity, maximum compressive stress and shear stress. During practicing their experiments, they evaluated both the modulus of resilience as the energy required to deform corn kernels to their yield points and the modulus of toughness as the energy required to deform the kernel to maximum compressive force. They reported that for corn kernels the values of modulus of resilience were 0.0136 and 0.0339 Joule per kernel for edge and flat positions respectively. They added that the values for moduli of toughness were 2 to 5 times greater than spectreive moduli of resilience.

Shelef and Mohsenin (1969) studied the effects of moisture content on mechanical properties of shelled con by applying uniaxial compression to individual kernels in the range of 6.5 to 28 % moisture content (dry basis) They determined the linear limit load, the apparent modulus of elasticity and the modulus of deformability using a cylindrical indenter and by parallel flat plates.

Kawaljit et al (2007) studied some physical and mechanical properties of grains for deferent Indian corn varieties. They concluded that the mechanical rupture force for corn grains showed a negative correlation with peak viscosity of flour. In the same time it was positively correlated with the amylase content of starch.

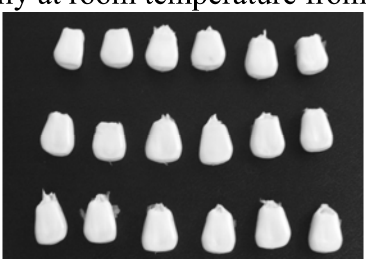
The aims of this study were to analyze:

1- Behavior of individual corn kernels under the effect of the force due to rigidity and force–deformation tests on both longitudinal and lateral positions of each kernel and due to penetration test on the embryo area.
2- Behavior of kernels in bulk condition under pressure-density relationship tests.

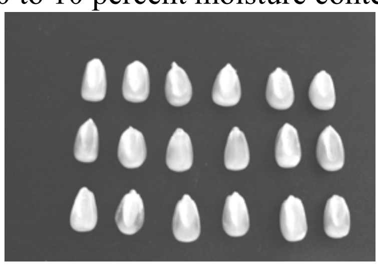
MATERIALS AND METHODS

Raw Materials

The hybrid corn kernels samples used in this investigation "white and yellow dent corn kernels, single hybrid 10 and single hybrid 155 respectively were collected from the research plots of Minufiya Univ., faculty of agriculture, Figure (1). The corn samples were hand picked, hand shelled and then dried naturally at room temperature from 30 to 10 percent moisture content.



a- White single hybrid-10



b- Yellow single hybrid-155

Figure (1) :Samples of hybrid corn kernels

All experiments and procedures were done in the laboratory of physical properties at Agriculture Engineering Department, Faculty of Agriculture, Alexandria University. Four levels of corn kernels moisture content were selected 35, 25, 15 and 10 % (w.b.) to conduct the physical characteristics tests.

The first sample of about 35 % (M.C.w.b.%) was shelled manually and the kernels were divided into samples of 500 grams each, packed in double polyethylene plastic bags tightly sealed and stored in the cold room refrigerator until used at 5 $\pm$ 0.5 ºC. The other two husked corn ear samples were subjected to natural aeration drying by spreading them on the bench under room temperature (20 ºC) for enough time to reduce its moisture level to the beneath level required for kernels to achieve three other nominal moisture levels of 25, 15 and 10 % (w.b.). The dried samples were prepared as the first one.

Moisture content of a sample of corn kernels was measured by drying about 15 grams of whole kernels for 72 hours at 103 ºC in a natural air oven (Nelson, 1980). The obtained moisture content was an average of 5 replicates.

The refrigerated corn samples were permitted to reach room temperature in the sealed bags before opening for tests and measurements. More attention was paid by measuring kernel moisture content of each sample test directly, after each test to get its actual moisture content.

Mechanical properties under study in this investigation were including experiments for the individual kernels, rigidity test; penetration test and force-deformation test; and experiments on the bulk of kernels, pressure density relationship test.

TESTS PROCEDURES:

a) **Rigidity Test:**

Randomized samples for every corn kernel variety were selected for each level of the concerned moistures. The test was done on kernels in two different positions; Longitudinal and Lateral as shown in figure (2).

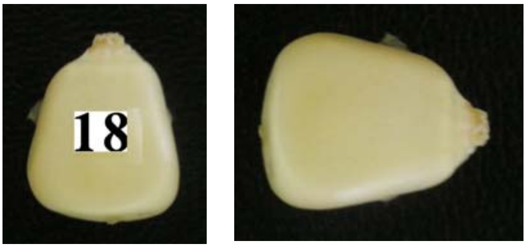


Figure (2):Longitudinal and lateral positions of the individual corn kernel

The samples were divided to 50 kernels from each variety for each moisture level. In three replicates for each test, 25 kernels were used for longitudinal test and 25 kernels were used for Lateral test. The dimensions in mm of all kernels were measured by a digital slide caliper of an accuracy of 0.01 mm. The weights of the corn kernels in g were conducted using an electrical digital balance model (ACCULAB–LT, Cole Parmer, Chicago) with a maximum capacity of 400 grams and 0.0001 gram accuracy. A Rigidity tester (Kiya Seisakusho LTD. Tokyo Japan) up to 20 kg and as shown in figure (3) with an accuracy 200 grams was used for measuring the rupture force on the two positions of corn kernels as shown in figure (2).

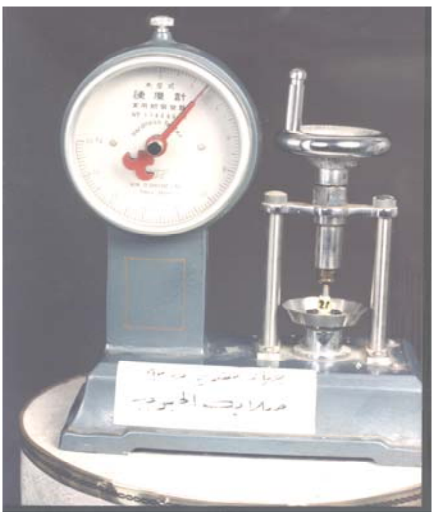


Figure (3): Rigidity Tester

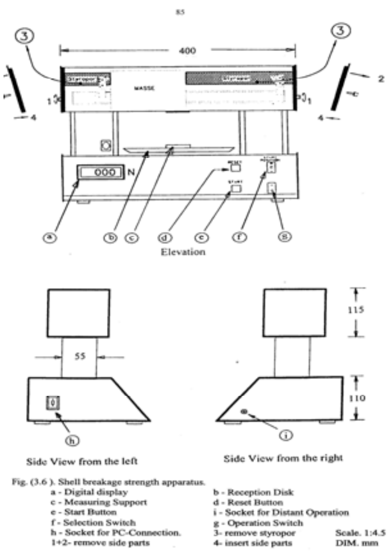


Figure (4): Breaking Strength Device

b) **Penetration Test**:

Ten randomized kernels from each corn variety and for each moisture level were selected and repeated 4 times to achieve penetration test. A breaking strength device (BMG 1.2 MC) up to 100 N was used for measuring the penetration force in the embryo area for individual kernels in a fixed division in each kernel as shown in Figure (4). The tool used in this test was 4.338 mm^2 cross section area. The pressure force on the kernels was measured in N. and it is sufficient to penetrate this division up to 1mm.Thus, a total of 320 kernels were tested. Kernel dimensions (length, L, - width, W, and thickness, T, in mm) and the weight (w, g,) of each kernel were determined also in this test.

c) **Force–Deformation Test :**

Kernels moisture contents at a range from 9.18 to 30.66% wet basis were attained for force-deformation test. Moisture contents were determined using an oven drying method (103C°, 72h) (ASAE, 1990) after the samples had naturally dried on the bench. Both the weight and dimensions of each kernel of the selected samples were recorded directly before the test. The dimensions were the length (L); upper and

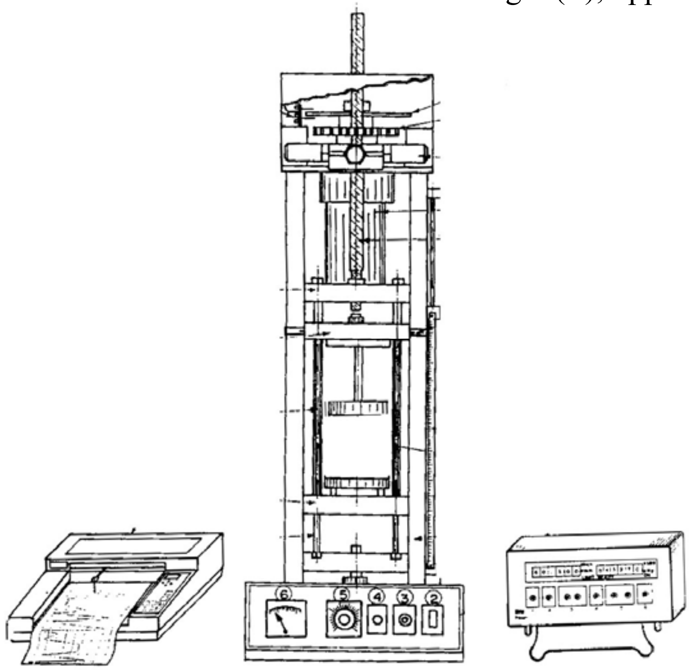


Figure (5): Instron Machine Cole Parmer Apparatus (model G-08232-28) lower widths (W_2, W_1) and thickness (T) in mm. The force-deformation tests were achieved on the individual complete corn kernels in two different positions (longitudinal and lateral) by using an Instron as shown in figure (5).

Experiments were run with chart speed of 20 cm/min and cross-head speed (deformation rate) of 10 mm per minute. The Instron Machine was necessary for measuring the applied load of force and the amount of corn kernel deformation as a function of time. Force deformation curves of each corn kernel of the two varieties were done for both longitudinal and lateral positions at the investigated range of moisture content. Rupture force(N), yield point (N), deformation at both rupture force and yield point (mm), energy required to deform corn kernel on the used position (N. m) and modulus of elasticity (kN/m)were calculated.

d) <u>Pressure Density Relationship Test</u>:

The pressure density characteristics are necessary for calculating the force required to compress kernels to the desired density and for the design of the compressing system. A pressure density relationship test for bulk of two corn kernel varieties was investigated for the moisture content range of 10 – 30% wet basis. Each sample of corn kernels variety of the desired moisture content was filled in a cylinder to its full depth without any compaction and the sample was weighted .The volume of the cylinder was 25.12 cm^3. The initial density for every sample at each moisture level was estimated.

A universal testing machine was used to achieve this test. The peak point (kg) was recorded for each sample. The rate of deformation was 20 mm/minute and the other specifications of the test were chart speed of 5 cm/minute and of span 500 mV. Force-deformation curve of each bulk sample was drawn and analyzed later for compression stress, MPa; strain and bulk density, kg /m^3, determinations. In the same time these analyze were used to determine compression strength MPa relationship with bulk density kg / m^3 for each corn sample variety at its moisture content.

RESULTS AND DISCUSSIONS

Rigidity Test

The results of rigidity tests were shown in figure (6) expressed as the influence of the position and both moisture content and weight of the exposed individual kernel to force by the rigidity tester. The moisture content of kernels for the experimented samples ranged from 9.88 to 29.84 and from 9.5 to 30.26 for white and yellow corn kernels varieties respectively. The breaking force decreased as the moisture content of the two varieties on the two positions increased. Meanwhile, it was positively correlated with the weight of kernel.

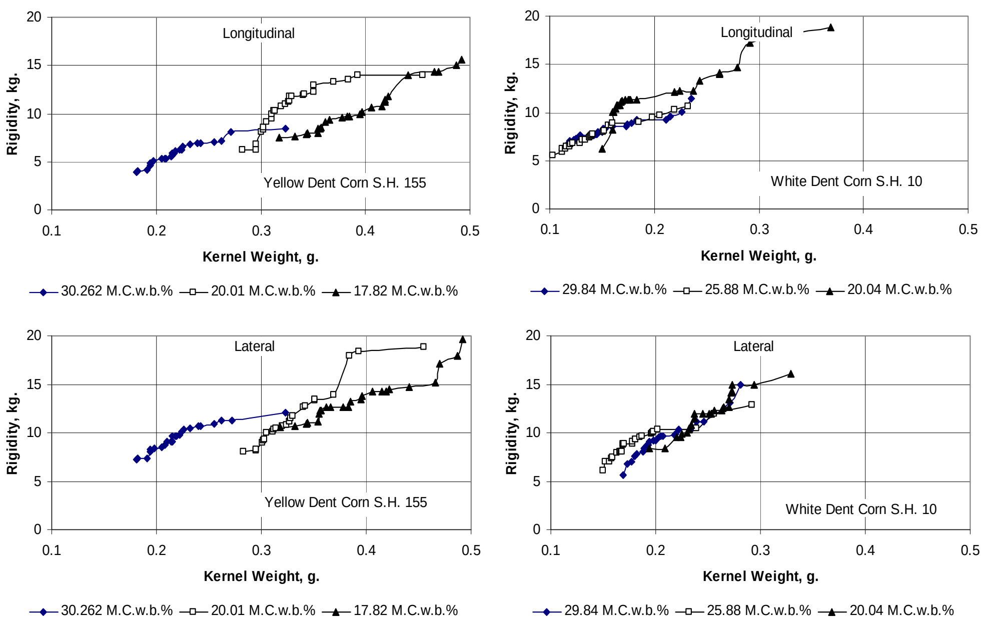


Figure (6): Rigidity of dent corn kernels varieties at two loading positions, longitudinal and lateral

The maximum and minimum values of the obtained rigidity force for the two white and yellow corn varieties on the longitudinal loading position were 174.152 and 44.598 , 147.758 and 38.462 (N) and laterally were 184.890 and 55.237 , 181.542 and 66.161 (N) respectively. This result indicates that the lateral loading on the individual kernel appeared more resistible for breakage than the longitudinal loading. A multiple regression analyses were achieved to explore the previous relationship. The analyses yielded the following multiple linear regression equations:

For White Corn Kernels

Longitudinal Loading

$$R, (N) = 167.7213 - 4.2113\ MC + 80.9056\ W, \quad \ldots\ldots R^2 = 0.715,\ SE = 19.3268$$

Lateral Loading

$$R, (N) = 147.5467 - 3.6936\ MC + 123.8942\ W, \quad \ldots\ldots R^2 = 0.671,\ SE = 17.6605$$

For Yellow Corn Kernels

Longitudinal Loading

$$R, (N) = 156.2307 - 3.7844\ MC + 48.9520\ W, \quad \ldots\ldots R^2 = 0.823\quad SE = 20.492$$

Lateral Loading

$$R, (N) = 130.6304 - 2.9975 MC + 134.8109\ W, \quad \ldots\ldots R^2 = 0.675\quad SE = 22.089$$

Where: R = rigidity force (N),
MC = moisture content % w.b ,
W = weight, g.

It was appeared from the analyses that the kernel moisture content strongly affect rigidity force with reversible effect while, the weight of the individual kernel was directly proportional with rigidity force.

Penetration Test:

The results of penetration tests were shown in figure (7). Penetration force (P, N) in the embryo area which considers fixed divisions for each individual corn kernel of all samples were recorded. This area is the softer on the kernel and so easy to attack from insects. The analyzed data revealed that moisture content and weight of each corn kernel, white and yellow varieties ranged from 9.5 to 30.076, from 10 to 35.3 % (w.b.) and from 0.1998 to 0.5606, from 0.2401 to 0.5668 (g). In this direction the related maximum and minimum values of penetration force were from 54.013 to 13.22 N for white variety and from 49.023 to 8.797 N for yellow variety. The dependence of the required penetration force to penetrate this fixed division for 1 mm depth could be realized from the following gained by analyses the multiple linear regression equations:

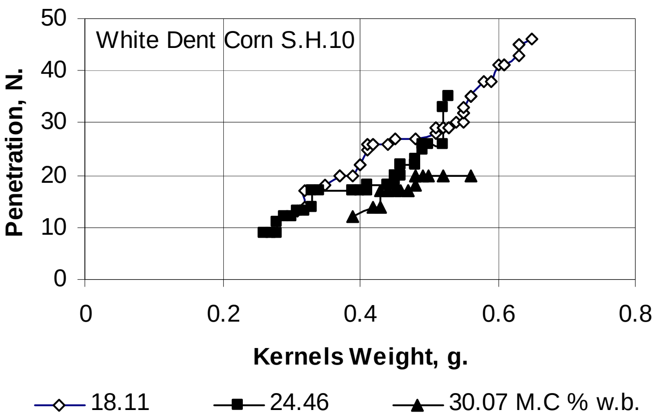
<u>For White Corn Kernels</u>

$$P, (N) = 63.6446 - 1.87066\ MC + 18.9293\ W, \quad \ldots\ldots R^2 = 0.834,\ SE= 3.563$$

<u>For Yellow Corn Kernels</u>

$$P, (N) = 43.2470 - 1.28962\ MC + 43.5545\ W, \quad \ldots\ldots R^2 = 0.777,\ SE = 4.783$$

It is clear from the equations of the two varieties that the corn kernels moisture content was inversely proportional to penetration force. Contrary, the weight of each corn kernel was directly proportional to penetration force.



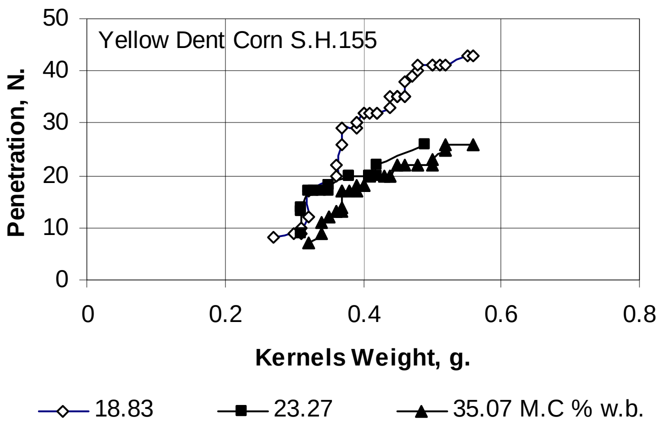
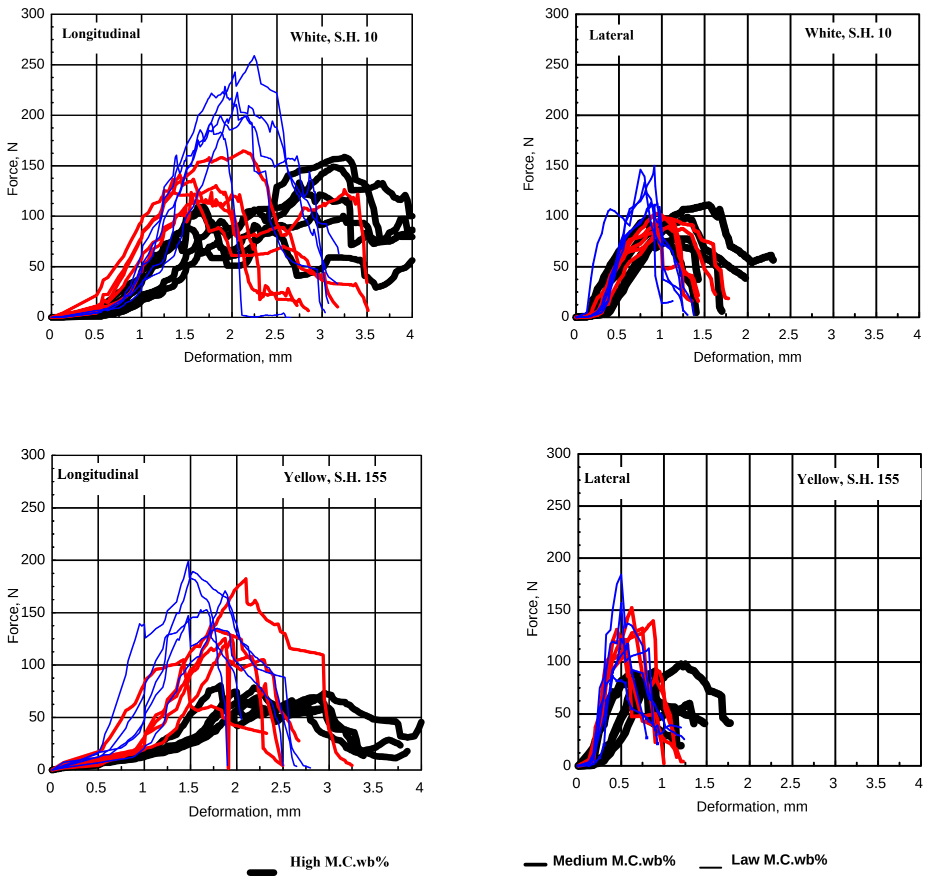


Figure (7): Penetration of dent corn kernels varieties.

Force deformation test on single kernels

Longitudinal and lateral compressions on the individual corn kernel of the two varieties in this test were practiced by using the Instron universal testing machine with the aim to reach the rupture state of the kernel. All tests were achieved under CHS of 10mm/min. Chart Speed of 20 cm/min and Span of 50 mV. In this regard, figure (8) illustrates force-deformation curves of dent corn kernels varieties at two loading positions longitudinal and lateral at different moisture levels. It is clear from the figure that generally, the material property, the required force to rupture the kernel increases as the moisture content of the individual corn kernel decreases.



Figure(8) :Force deformation curves of dent corn kernels varieties.

Also the analysis of rupture force (RF, N) data versus each of kernel moisture content and kernel weight are represented in the following multiple linear regression equations which clarify that relation

<u>For White Corn Kernels</u>

Longitudinal

RF=345.0236 - 16.0401 MC + 493.2637 W

…………………R^2 = 0.875 SE = 17.518

Lateral

RF=195.5418 - 5.7779 MC + 126.6717 W

……………….. R^2 = 0.645 SE = 13.789

<u>For Yellow Corn Kernels</u>

Longitudinal

RF=221.0045 - 7.0649 MC + 159.6598 W

…………………R^2 = 0.795 SE = 12.647

Lateral

RF=102.0919 - 3.8404 MC + 242.6311 W

………………….R^2 = 0.685 SE= 14.657

In the same time, the equations reflect the positive correlation between the rupture force and the weight of the individual corn kernel on the two positions .

The plotted force deformation curves in a range of moisture content from about 10 to 35 % w,b for the corn kernels of the two varieties were used to extract and calculate yield force(N), yield deformation (mm), rupture force (N), rupture deformation (mm), elasticity modulus (N/m), yield energy (N.m) and rupture energy (N.m). The moisture dependant of the previous determined mechanical properties were analyzed and yielded the following linear regression equations which describe this closed relation.

For White Corn Kernels S.H.10 "Longitudinal"

YF, (N)	= 274.807 – 6.477 M ,	R^2 = 0.784 ,	SE = 14.681
YD, mm	= - 0.192 + 0.065 M ,	R^2 = 0.825 ,	SE = 0.130
RF, (N)	= 442.127 – 11.066 M ,	R^2 = 0.868 ,	SE = 18.636
RD, mm	= - 1.202 + 0.132 M ,	R^2 = 0.772 ,	SE = 0.3107
E, (kN/m)	= 731.688 – 21.808 M ,	R^2 = 0.895 ,	SE = 32.281
YE, (N.m)	= 0.179 – 0.0051 M ,	R^2 = 0.900 ,	SE = 0.0073
RE, (N.m)	= 0.423 – 0.0116 M ,	R^2 = 0.803 ,	SE = 0.0246

For White Corn Kernels S.H.10 "Lateral"

YF, (N)	= 159.309 – 3.382 M	R^2 = 0.841 , SE = 6.358
YD, mm	= - 0.450 + 0.043 M	R^2 = 0.733 , SE = 0.113
RF, (N)	= 196.281 – 3.669 M	R^2 = 0.684 , SE = 10.773
RD, mm	= - 0.246 + 0.049 M	R^2 = 0.604 , SE = 0.171
E, (kN/m)	= 773.967 – 21.487 M	R^2 = 0.854 , SE = 38.403
YE, (N.m)	= 0.073 – 0.0022 M	R^2 = 0.879 , SE = 0.003
RE, (N.m)	= 0.110 – 0.0024 M	R^2 = 0.691 , SE = 0.011

For Yellow Corn Kernels S.H.155 "Longitudinal"

YF, (N)	= 225.304 – 5.460 M	R^2 = 0.846 , SE = 13.529
YD, mm	= 0.5264 + 0.047 M	R^2 = 0.765 , SE = 0.153
RF, (N)	= 301.347 – 7.624 M	R^2 = 0.821 , SE = 20.697
RD, mm	= 0.842 + 0.043 M	R^2 = 0.754 , SE = 0.143
E, (kN/m)	= 348.241 – 8.050 M	R^2 = 0.716 , SE = 29.485
YE, (N.m)	= 0.095 – 0.002 M	R^2 = 0.618 , SE = 0.014
RE, (N.m)	= 0.171 – 0.004 M	R^2 = 0.743 , SE = 0.014

For Yellow Corn Kernels S.H.155 "Lateral"

YF, (N)	= 163.669 – 3.16229 M	R^2 = 0.665 , SE = 13.075
YD, mm	= -0.065 + 0.02293 M	R^2 = 0.713 , SE = 0.084
RF, (N)	= 220.365 – 4.47661 M	R^2 = 0.669 , SE = 18.331
RD, mm	= -0.120 + 0.03444 M	R^2 = 0.745 , SE = 0.117
E, (kN/m)	= 1250.382 – 35.543 M	R^2 = 0.676 , SE = 17.766
YE, (N.m)	= 0.026 – 0.0006 M	R^2 = 0.713 , SE = 0.002
RE, (N.m)	= 0.087 – 0.002 M	R^2 = 0.602 , SE = 0.0108

It was clear from the previous linear regression equations gained by analyzing all the obtained data from force-deformation test that the moisture content of the corn kernels of the two varieties had a large influence on the material properties. The values of the deformation at the yield point and at the point of rupture force generally increased with increasing the moisture content of the corn kernels of the two varieties. Both the values of the rupture force and the force at the yield point showed the opposite results, that is, these important forces decreased linearly when the moisture content of the kernels of the two varieties increased in the range from 10 to 35 (%, w.b.) .Similarly, the energy required to rupture the individual corn kernel on the two positions - longitudinal and lateral – and the energy at the yield point showed an inverse effect with increasing of the moisture content. Table(1) summarizes the mean values of the mechanical properties related to force-deformation test on the two positions of the complete individual corn kernel for the two varieties at the range of moisture content from 10 to 35 % w.b. It can be seen from the table that the location of the force on the kernel affect the values of the material properties as well as its moisture content.

Table(1): Mechanical Properties Related To Force-Deformation Test

White Corn Kernels S.H.10 "Longitudinal"

M.C. wb%	YF, (N)	YD, mm	RF, (N)	RD, mm	E, (kN/m)	YE, (N. m)	RE, (N. m)
9.81	210.033	0.465	331.458	0.122	513.606	0.1276	0.3069
14.63	177.646	0.795	276.124	0.784	404.565	0.1019	0.2489
19.42	145.259	1.124	220.789	1.446	295.524	0.0762	0.1908
24.94	112.872	1.453	165.455	2.109	186.483	0.0505	0.1328
29.33	80.485	1.782	110.120	2.771	77.442	0.0248	0.0747
34.46	48.097	2.111	54.786	3.434	31.598	0.008	0.0167

White Corn Kernels S.H.10 "LATERAL"

M.C. wb%	YF, (N)	YD, mm	RF, (N)	RD, mm	E, (kN/m)	YE, (N. m)	RE, (N. m)
9.81	125.482	0.015	159.583	0.243	559.097	0.0506	0.0854
14.63	108.568	0.201	141.234	0.488	451.662	0.0393	0.0730
19.42	91.654	0.419	122.885	0.733	344.227	0.0279	0.0606
24.94	74.741	0.636	104.536	0.978	236.792	0.0166	0.0482
29.33	57.827	0.853	86.187	1.223	129.357	0.0052	0.0358
34.46	40.913	1.071	67.838	1.468	21.922	0.0061	0.0234

Yellow Corn Kernels S.H.155 "Longitudinal"

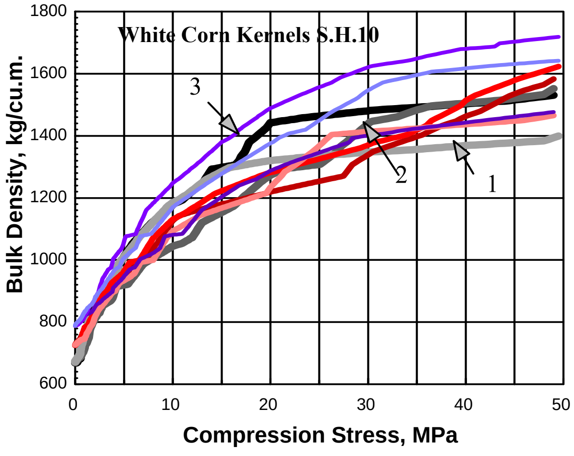
M.C. wb%	YF, (N)	YD, mm	RF, (N)	RD, mm	E, (kN/m)	YE, (N. m)	RE, (N. m)
10.12	170.698	1.002	225.102	1.272	267.733	0.0741	0.1293
14.48	143.394	1.239	186.979	1.488	227.480	0.0632	0.1084
20.63	116.091	1.477	148.856	1.703	187.226	0.0524	0.0875
25.37	88.787	1.715	110.734	1.918	146.972	0.0415	0.0666
29.72	61.484	1.953	72.611	2.134	106.719	0.0307	0.0457
35.31	34.181	2.190	34.488	2.349	66.465	0.0198	0.0248

Yellow Corn Kernels S.H.155 "Lateral"

M.C. wb%	YF, (N)	YD, mm	RF, (N)	RD, mm	E, (kN/m)	YE, (N. m)	RE, (N. m)
10.12	132.046	0.163	175.599	0.224	894.951	0.0199	0.0645
14.48	116.235	0.278	153.216	0.396	717.235	0.0169	0.0532
20.63	100.424	0.393	130.833	0.568	539.520	0.0138	0.0420
25.37	84.612	0.507	108.450	0.740	361.804	0.0108	0.0307
29.72	68.801	0.622	86.067	0.912	184.089	0.0077	0.0195
35.31	52.989	0.737	63.684	1.085	63.735	0.0047	0.0082

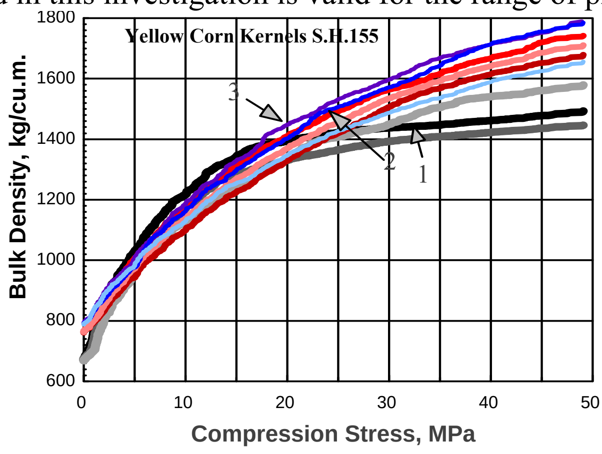
Pressure Density Relationship

Figures 9 and 10 represent the plots of the pressure values versus the density values for the two corn kernels varieties studied in this investigation, white dent corn single hybrid 10 and yellow dent corn single hybrid 155. It is clear from the illustrated curves that bulk density of the kernels of the two corn varieties increased sharply from 0 to 10 MPa i.e. the largest change in the bulk density occurred at pressure levels below 10 MPa. These changes are as a result of the rearrangement of particles in the cylinder. The increments in bulk density with pressure declined gradually and reached a constant when the pressure increased from 10 to 20 MPa. Increasing pressure from 20 MPa, bulk density increased linearly .It is also apparent from the curves that at 50 MPa pressure, bulk densities ranged from 1500 to 1720 kg/m^3 for white dent corn single hybrid 10 and from 1480 to 1800 kg/m^3 for yellow dent corn single hybrid 155 . Bulk densities of the yellow corn kernels were larger than those for white corn kernels, it may be due to its physical characteristics.



Figure(9) :Pressure density curves for white dent corn kernels-Single Hybrid 10- at different levels of moisture content .

It is apparent also that at the same pressure, bulk densities of the two varieties increased as the moisture content of the kernels increase. The relationship between the bulk density of the corn kernels and pressure obtained in this investigation is valid for the range of pressure tested.



Figure(10) :Pressure density curves for Yellow dent corn kernels-Single Hybrid 155- at different levels of moisture content .

Multiple Regression analysis were conducted on the date related to bulk density- Compression stress relation ship to obtain a functional relationship expressing bulk density (kg/cu.m.) of the kernels of the two verities as a function of compression stress (CS, MPa) and moisture content (MC, w.b.%). The once which provided the best fitting of data are:

<u>For White Dent Corn Kernls:</u>

$$\text{Bulk Density} = 1058.215 + 19.0716\ CS - 9.1315\ MC \quad \ldots\ldots\ldots\ldots R^2 = 0.844 \quad SE = 48.879$$

<u>For Yellow Dent Corn Kernls:</u>

$$\text{Bulk Density} = 975.953 + 21.019\ CS - 5.118\ MC \quad \ldots\ldots\ldots\ldots R^2 = 0.893 \quad SE = 46.348$$

The analyzed data and represented in figure (11) illustrate stress-strain behavior when samples in bulk were subjected to presser.

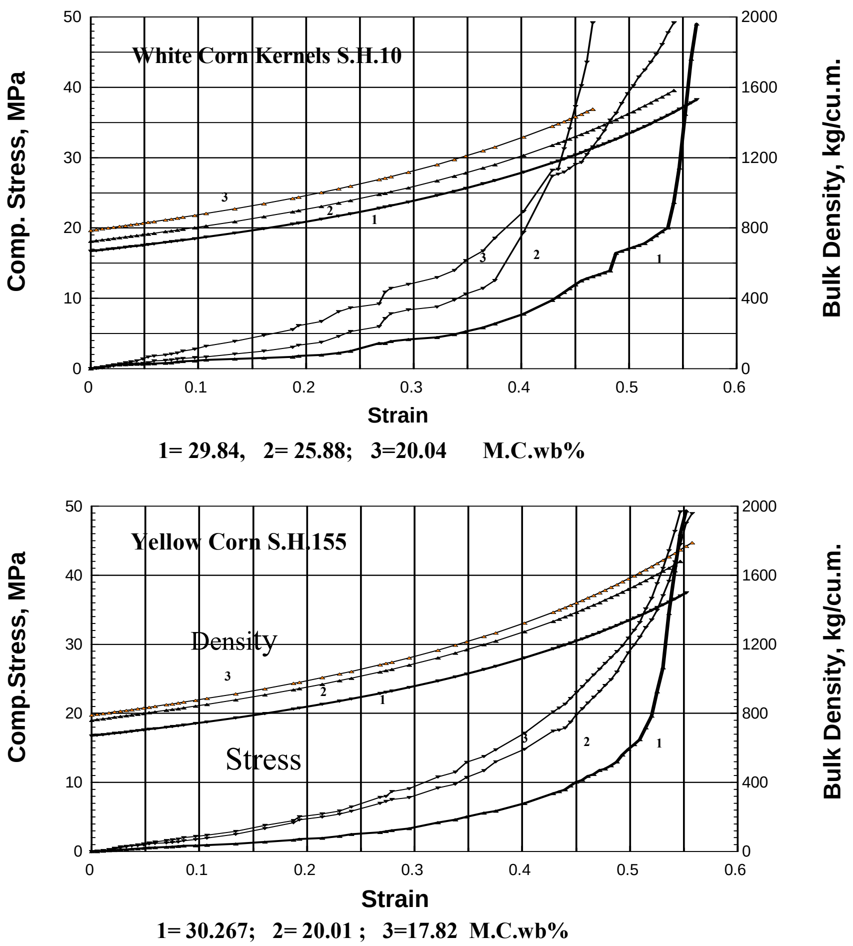


Figure (11): Pressure-Strain-Bulk Density Curves of Corn Kernels at Different Levels of Moisture Content

Data collected from this test were used to plot all curves to express pressure-density relationship for the two corn kernel varieties at three different levels of moisture content as shown in figures 9 and 10. Figure (11) shows the initial low pressure up to 0.2 MPa required to compress and deform corn kernels of each sample. The same figure also demonstrates both the gradual and sharp increasing in the required pressure and its relation with the strain happened in each corn kernel sample. It is apparent from the stress-strain curves that no significant differences were found in the compressibility of the yellow dent corn single hybrid 155 at pressure range from 40 to 50 MPa at its moisture levels. It is obvious when comparing the strain at the same pressure range that the white corn variety was more compressible than yellow corn variety at a high moisture content than at a low moisture content.

Regression analysis were conducted on the date related to stress-strain relation ship to obtain a functional relationship expressing strain (ε) of the kernels of the two verities as a function of compression stress (CS, MPa) and moisture content (MC, w.b.%). The exponential function was the best fitting of data :

<u>For White Dent Corn Kernls:</u>

$$e^{\varepsilon} = 0.9684 + 0.01693\ CS + 0.00661\ MC$$

$$\varepsilon = Ln\ (0.9684 + 0.01693\ CS + 0.00661\ MC)$$

…………. $R^2 = 0.784$ SE = 0.1131

<u>For Yellow Dent Corn Kernls:</u>

$$e^{\varepsilon} = 0.9582 + 0.0181\ CS + 0.00752\ MC$$

$$\varepsilon = Ln\ (0.9684 + 0.01693\ CS + 0.00661\ MC)$$

…………. $R^2 = 0.829$ SE = 0.1038

CONCLUSION

-From rigidity test the breaking force decreased as the moisture content of the two varieties on the two positions increased. Meanwhile, it was positively correlated with the weight of kernel at range of moisture content of kernels from 9.88 to 29.84% and from 9.5 to 30.26% for white and yellow varieties respectively. The lateral loading on the individual kernel appeared more resistance for breakage than the longitudinal loading.

-From penetration test the corn kernel moisture content was inversely proportional to penetration force on the embryo area. Contrary, the weight of each corn kernel was directly proportional to penetration force.

- The obtained data from force-deformation test showed that the moisture content of the corn kernels of the two varieties had a large influence on the force deformation parameters:

    *The values of the deformation at the yield point and at the point of rupture force generally increased with increasing the moisture content.

    *Both the values of the rupture force and the force at the yield point decreased linearly when the moisture content of the kernels of the two varieties increased in the range from 10 to 30 (%w.b) .

    *Energy required rupturing the individual corn kernel on the two positions -longitudinal and lateral – and the energy at the yield point showed an inverse effect with increasing of the moisture content.

    *Elasticity modulus was inversely proportional with moisture content of the individual corn kernel on the two positions.

-For tests on kernels in bulk, it was appeared that at the same pressure, bulk densities of the two varieties decreased as the moisture content of the kernels increase. Also comparing the strain at the same pressure range yielded that the white corn variety was more compressible than yellow corn variety at high moisture content than at low moisture content.

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الملخص العربي

الخواص الميكانيكية لحبوب الذرة

محمد عبد الفتاح عبد المقصود[1]

تم في هدا البحث دراسة الخواص الميكانيكية لحبوب صنفين من الذرة المصرية وهما صنف الذرة البيضاء هجين فردي ١٠ وصنف الذرة الصفراء هجين فردي ١٥٥وعلاقتها بمحتوى الرطوبة للحبوب لما له من الأهمية.

و قد انقسمت الدراسة إلى جزأين رئيسيين، الأول اختص بالحبة الفردية أما الثاني فقد تعلق بالحبوب في صورتها الكمية. و في هذا الخصوص كان الهدف من الدراسة الأتي :

- دراسة سلوك الحبوب الفردية تحت تأثير القوي نتيجة لكل من اختبارات الصلابة و الاختراق واختبارا لقوة و الإزاحة عند الانضغاط.

- دراسة سلوك الحبوب الكمية تحت تأثير القوي نتيجة لإختبار علاقة الكثافة بالضغط.

و بالتالي اشتملت الخواص المتعلقة بالجزء الأول :

* قوة الصلابة في الاتجاهين الطولي و العرضي للحبة و علاقتها بكل من الوزن والمحتوي الرطوبة للحبة الفردية، وقد استخدم جهاز قياس الصلابة للحبة بسعة ٢٠ كجم ودقة ٢٠٠ جم (kiya Seisakusho LTD. Tokyo Japan) .
* قوة اختراق منطقة الجنين للحبة وعلاقتها بكل من الوزن والمحتوي الرطوبة للحبة الفردية وقد استخدم جهاز خاص بقياس إجهاد الكسر (BMG 1.2 MC) .
* في اختبار القوة الإزاحة كل من القوة اللازمة للتحطيم والإزاحة والطاقة اللازمة للتحطيم ومعامل المرونة خلال مرحلة الخضوع وعلاقتها بمحتوي الرطوبة في الاتجاهين الطولي والعرضي للحبة الفردية، وقد استخدم جهاز قياس الإنسترون لقياس هذه الخواص (Instron Machine Cole Parner Apparatus,(model G-08232-28).

واشتملت الخواص المتعلقة بالجزء الثاني :

الإجهاد الإنفعال الكمي وكذلك اجهاد الضغط وعلاقتة بالكثافة الكمية لحبوب الذرة عند مستويات رطوبية مختلفة

وكانت أهم نتائج ا لدراسة الأتي:

أولا اختبارات تأثير القوى على الحبوب الفردية:

١-الصلابة:

تراوحت قيم صلابة الحبوب الفردية في الأتجاة الطولي من ٤٤.٥٩٨ الي ١٧٤.١٥٢ نيوتن ومن ٣٨.٤٦٢ الي ١٤٧.٧٥٨ نيوتن و في الأتجاة العرضي من٥٥.٢٣٧ الي١٨٤.٨٩ نيوتن ومن٦٦.١٦١ الي ١٨١.٥٤٢ نيوتن لصنفي الذرة البيضاء و الصفراء علي التوالي .

١- استاذ مساعد هندسة زراعية بكلية الزراعة جامعة المنوفية.

كما اظهر الأتجاة العرضي مقاومة أعلي للكسر عنة في الأتجاة الطولي. المحتوي الرطوبي للحبة يتناسب عكسيا مع صلابة الحبوب الفردية في ألمدي من ١٩ الي٣٠% علي أساس رطب بينما يتناسب طردياً مع وزن الحبة.

٢- قوة إختراق منطقة الجنين للحبة:

- تراوحت قيم هذه القوة بين ١٣.٢٢ و٥٤.٠١٣ نيوتن وبين ٨.٧٩٧ و٤٩.٠٢٣ نيوتن لصنفي الذرة البيضاء و الصفراء علي التوالي في نفس الوقت كانت لها تناسبا عكسيا مع المحتوي الرطوبي للحبة في مدي الدراسة المستخدم.

٣-بتحليل نتائج منحنيات القوة-الإزاحة عند مدي الرطوبة للحبوب من١٠ الي٣٥ % وجد انه :

- توجد علاقة عكسية بين القوة اللازمة لتكسير الحبة و المحتوي الرطوبي في حين تزداد هذه القوة بزيادة وزنها.
- الازاحة عند نقطة الخضوع وكذلك عند نقطة التحطيم تزداد بزيادة المحتوي الرطوبي للحبة.
- كل من قوة التحطيم للحبوب الفردية و القوة عند نقطة الخضوع تقل خطيا بزيادة المحتوي الرطوبي وكذلك الطاقة اللازمة لتحطيم الحبة في الاتجاهين.
- معامل المرونة تناسب عكسيا مع المحتوي الرطوبي للحبة لصنفي الذرة وعند تأثير القوة في الاتجاهين الطولي و العرضي لها.

ثانيا اختبارات تأثير القوى على الحبوب الكمية

- إختبارات علاقة الكثافة بالضغط
- كان هناك علاقة عكسية بين كثافة الحبوب الكمية و المحتوي الرطوبي عند نفس مستويات الضغوط لكلا الصنفين من حبوب الذرة .

كانت حبوب الذرة البيضاء أكثر قابلية للانضغاطية من الحبوب الصفراء وخاصة عند المحتوي الرطوبي المنخفض للحبوب.