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Original Article

Effects of Moisture Contents on Harvesting time and Drying Methods on Mechanical Properties and Electrical Conductivity of Corn Hybrids

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ABSTRACT

Background and Objectives: Drying affects quality parameters of the grains. The objective of this study was to investigate effects of drying methods, moisture contents at harvesting time and corn hybrids on mechanical properties (deformation, rupture force, firmness, necessary energy and power and toughness at rupture points) and electrical conductivity of corn kernels.

Materials and Methods: The study assessed four corn hybrids (Ns640, Jeta600, Konsur580 and SC704) harvested at various moisture contents (20, 30 and 40%) and dried using two drying methods (sun dried and artificially dried using oven at 85–90 °C).

Results: Results revealed that corn variety significantly affected mechanical properties since Ns640 included the maximum and Konsur580 the minimum properties, compared to that other hybrids did. Furthermore, variety affected electrical conductivity. Konsur580 variety exhibited a higher electrical conductivity in both drying methods. Moisture contents at harvesting time significantly affected all mechanical properties, except deformation and firmness, in the two drying methods. Higher values of mechanical properties were achieved at 20% moisture. Moreover, effects of the moisture contents on electrical conductivity were significant and kernels with 40% moisture at harvesting time included higher electrical conductivities.

Conclusions: Drying methods of corn significantly affected quality parameters and electrical conductivity. Corn kernels dried in sun included higher levels of properties such as rupture force, necessary energy and power, toughness and lower levels of electrical conductivity.

Keywords: Maize, Drying method, Harvesting time, Mechanical properties, Electrical conductivity

Introduction

Corn (*Zea mays* L.) is one of the most important cereal crops with widespread cultivations worldwide due to its high yield and various uses followed by rice and wheat. Corn is important due to its uses in animal and human feeds as well as oil production. One of the most important factors affecting product quality such as corn quality is the harvesting time, which depends on environmental conditions. High water (moisture) contents of seeds at harvesting time, is one of the negative factors on quality. Farmers usually have problems for the safe storage of corn grains due to high water contents (20–35%) at harvesting time, especially in areas with unfavorable conditions for drying crops in fields. The major aim of crop drying is to decrease water contents of the agricultural products to the optimum range of storage of nearly 12% (1). During drying processes, moisture of the product decreases using thermal energy (2). Because of the moisture removal and build up a water gradient, structure of the dried mater changes and internal cracks occur by shrinkage stresses. Changes depend on the moisture content, texture, and method of drying. Stress increases breakage of the structure of dried products and subsequently decreases quality and germination (3–5). Beke et al. (6) studied effects of drying temperature and moisture of grains on properties of the dried grain such as mechanical, biological and chemical properties and reported that the studied parameters were the most important factors.

Studies have described mechanical properties of the biological materials as well as force-deformation curves from uniaxial compression tests, using martial testing

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machine (7–10). Based on this method, studies have been carried out to investigate effects of drying on quality parameters of grains for various means. Seifi and Alimardani (11) reported that mechanical and physical properties of two cultivars of corn (DC370 and SC407) were affected by the moisture contents of kernels. Minaei et al. (12) showed that the breakage of rice grains increased by drying temperatures and crack of the grains was lower at higher moisture contents of the rice products. Davidson et al. (13) assessed the stress cracking and breakage susceptibility of a corn hybrid as affected by drying temperatures from 40 to 100 °C and showed that increases in drying temperatures caused significant stress cracking and breakage. Montanuci et al. (14) investigated effects of drying temperature on moisture, density, drying breakage and shrinkage of the corn grains using two drying methods of oven and pilot dryer and reported that increases in temperature increased the grain breakage in the two drying methods but decreased drying time, final moisture and shrinkage of the grains. Mechanical resistance of the grains/seeds to impact damages plays an important role in designing of harvesting and other processing machines (15). This basic information is necessary because during operation of these machines, grains are subjected to impact loads, which may result in mechanical damages. Impact damage of seeds depends on several factors, including impact velocity, seed structural features, variety and moisture content, stage of ripeness, fertilization level and incorrect setting of the particular working subassemblies of machines (16–18).

Losses in membrane integrity cause leaching of the cell solutions in various quantities as a function of the seed deterioration degree and the damage urges use of rapid tests for the assessment of seed viability and potency (19). Seeds with low viability and potency show a higher solution leaching than that vigorous seeds with high germination rates do (20). Therefore, electrical conductivity (EC) test is usually selected since quality of the kernels is indirectly assessed by calculating levels of leachates in seed soaking solutions. Moreover, EC is a good indicator of the damage level and tegument integrity. Literature reviews show that studies have been carried out on effects of agricultural factors such as harvesting time on corn yields. However, consistent information are missing on variations of mechanical properties and electrical conductivity affected by variety, moisture content at harvesting time and drying method of the corn kernels. Therefore, the major aims of the current study were to assess effects of conventional variety (Ns640, Jeta600, Konsur580 and SC704), moisture content at harvesting time (20, 30 and 40%) and drying method (oven and sun drying) on mechanical properties (deformation, rupture force, firmness, necessary energy and power and toughness at the rupture point) and electrical conductivity of corns.

Materials and Methods

In this study, effects of moisture contents at harvesting time and drying methods on mechanical properties and electrical conductivity of the corn hybrids were studied. Four corn hybrids of Ns640, Jeta600, Konsur580 and SC704, as the major factors, and three moisture contents of kernels at harvesting time of 20, 30 and 40% (wet basis), as subfactor, were used. A field experiment as a split-plot with four replications based on randomized complete block design (RCBD) was conducted in Khoram Abad Research Station, Khoram Abad, Iran.

The corn seeds were cultured in form of hill planting (3 to 4 grains in each whole at 5 cm deep) with a distance of 18 cm between the plants on the rows. The distance between rows was 75 cm. Thinning was performed in the four to five leaf stage. Each corn hybrid was planted in 12 rows and the four planting lines of each hybrid were harvested at one time. The chemical fertilizers, including NPK based on the results of soil tests, were used as 300 kg/ha of nitrogen in form of urea, 150 kg/ha of phosphorous in form of superphosphate triple and 50 kg/ha of potash in form of potassium sulfate. Elimination of weeds was carried out using two mechanical and chemical methods (Equip herbicide with a ratio of 2.5 L ha^{-1}). Harvesting was carried out by hands based on the moisture contents of grains (20, 30, and 40%, wet bases) using moisture meter device (Rasa, Model 3000, Iran). Ears of the two middle rows were harvested by 50 cm from two sides. After harvesting, grains were immediately separated from ears and grain samples from each variety with various moisture levels were divided into two subplots. One of the subplots was transferred to an airfield and dried to nearly 12% of its moisture content and the other subplot was dried at 85–90 °C in an oven to nearly 12% of its moisture content. Then, samples were cooled at room temperature before assessing their mechanical properties and electrical conductivity. Mechanical properties of corns were assessed using universal testing machine (Zwick Roell, Germany), including a load cell with an accuracy of 0.01 N in force and 0.001 mm in deformation. For each treatment, 20 kernels (20 replications) were randomly selected. For each test, the individual kern was positioned horizontally with the major axis between two parallel plates of the machine and loaded at 2 mm/min speed until rapture. For each experiment, failure force and displacement at the failure point were achieved from the force-deformation diagram. Energy consumption at the failure point of the samples was assessed by calculating the surface area under the force-displacement curve directly using machine software (21). Firmness Q (N mm^{-1}) for corn kernels was calculated using Eq. 1 (22):

$$Q = \frac{F}{D} \tag{1}$$

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Where, F was the failure force (N) and D was the displacement at failure point (mm). Power necessary for the corn kernel rupture [P (W)] was calculated using Eq. 2 (22):

$$P = \frac{ES}{60000D} \qquad (2)$$

Where, E was the necessary energy for material failure (mJ); S was the loading rate (mm/min) and D was the displacement at failure point (mm). Toughness T (mJ mm^{-3}), ability of a material to absorb energy and plastically deform with no fractures, was calculated using Eq. 3 (7, 22):

$$T = \frac{E}{V} \qquad (3)$$

Where, E was the necessary energy for material failure (mJ); V was the volume of kernels (mm^3) calculated by measuring dimensions of the kernel (major diameter (a), minor diameter (b) and thickness (c) in millimeter) using Eq. 4 (23):

$$V = \frac{\pi B^2 a^2}{6(2a - B)} \qquad (4)$$

Where, B = (bc)$^{1/2}$. To assess electrical conductivity, kernels were mixed with nearly 250 ml of deionized water and stored at 20 °C for 24 h. Electrical conductivity of the treatments was calculated using electrical conductivity meter (JENWAY 4010: UK).

Results

Mechanical properties

Deformation at the rupture point

Results from the variance analysis of data showed that effects of the corn hybrid on deformation of corn kernels at the rupture point in sun-drying method was significant at 1% probability level. However, no significant differences were seen between deformations of the corn hybrids in oven drying method (Table 1). Results of the mean comparison in sun-drying method showed that Ns640 hybrid included the highest displacement at the rupture point (0.419 mm), compared to that other hybrids did (Table 2). In both drying methods, effects of the moisture content at harvesting time and interaction effects of the moisture content with corn hybrid on the kernel deformation were not significant. Furthermore, results from two-sided t-test showed no significant differences between the deformations of corn kernels at the rupture point in the two drying methods (Table 3).

Table 1. Results of the analysis of variance (mean square error) for the mechanical properties and electrical conductivity of corn kernels using oven and sun drying methods

Drying method	Source of variation	Df	Mechanical properties						Electrical conductivity
			Deformation	Rupture force	Firmness	The energy required for kernels rupture	Power required for kernels rupture	Toughness	
Oven drying	Block	3	0.00373^{ns}	548.501^{ns}	2480.175^{ns}	200.834^{ns}	4.680^{ns}	0.00615^{ns}	7971.761^{ns}
	Hybrid	3	0.00335^{ns}	2982.99^{**}	23662.106^{*}	298.964^{*}	1.479^{**}	0.01154^{**}	22105.084^{**}
	Error 1	9	0.00126	386.017	3679.511	52.492	1.251	0.00195	2901.577
	Moisture	2	0.00596^{ns}	3517.07^{**}	1750.700^{ns}	419.068^{*}	1.212^{*}	0.0116^{*}	27643.980^{**}
	Hybrid× Moisture	6	0.00070^{ns}	44.605^{ns}	2226.156^{ns}	35.357^{ns}	1.955^{ns}	0.00209^{ns}	8373.138^{*}
	Error 2	24	0.00287	455.702	6993.414	74.786	0.00000029	0.00226	3265.668
	C.V	-	15.13	10.4	14.265	23.494	15.65	25.05	9.644
Sun drying	Block	3	0.000250^{ns}	358.379^{ns}	6199.424^{ns}	84.943^{ns}	2.869^{ns}	0.00195^{ns}	1772.006^{ns}
	Hybrid	3	0.0147^{**}	3193.853^{**}	22950.483^{**}	328.814^{**}	3.002^{**}	0.01161^{**}	20686.434^{**}
	Error 1	9	0.00108	259.316	1193.222	30.908	1.672	0.00137	2125.879
	Moisture	2	0.00436^{ns}	1335.990^{*}	2854.841^{ns}	394.102^{**}	2.687^{**}	0.01271^{**}	11910.773^{**}
	Hybrid× Moisture	6	0.00055^{ns}	123.351^{ns}	774.622^{ns}	34.477^{ns}	2.180^{ns}	0.00223^{ns}	1225.598^{ns}
	Error 2	24	0.00221	265.484	3398.105	24.927	0.00000023	0.00099	1442.503
	C.V	-	12.58	7.43	9.89	12.29	13.02	15.66	7.47

**-Significant at 1%level.*- Significant at 5%level.^{ns}- not Significant.

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Table 2. Mean comparisons of the mechanical properties and electrical conductivity of corn kernels affected by corn hybrid and kernel moisture contents at harvesting time using oven and sun drying methods

Drying method	Independent variable	Mechanical properties						Electrical conductivity (µS/cm/g)
		Deformation (mm)	Rupture force (N)	Firmness (N mm^{-1})	The energy required for kernels rupture (mJ)	Power required for kernels rupture (×10^{-3}W)	Toughness (mJ mm^{-3})	
Oven Drying	Corn Hybrid							
	Jeta600	0.358a*	217.799a	610.78a	38.100ab	3.558ab	0.196ab	563.46 b
	Sc704	0.330a	203.300a	623.11a	33.035b	3.292bc	0.161b	582.74 b
	Ns640	0.370a	215.931a	587.62ab	43.329a	3.858a	0.230a	568.25 b
	Konsur580	0.356a	183.560b	523.37b	32.769b	3.042c	0.171b	655.74 a
	Kernel moisture (%)							
	20	0.375a	221.295a	594.96a	42.138a	3.706a	0.219a	547.09 b
	30	0.350a	201.998b	589.08a	36.354ab	3.450ab	0.184b	601.93 a
	40	0.337a	192.149b	574.63a	31.933b	3.156b	0.166b	628.62 a
Sun drying	Corn Hybrid							
	Jeta600	0.361bc	225.950a	614.69a	38. 402b	3.808b	0.210b	485.22b
	Sc704	0.336c	221.906a	625.44a	37.998b	3.500bc	0.172c	497.09b
	Ns640	0.419a	233.083a	588.37a	48.446a	4.300a	0.241a	480.49b
	Konsur580	0.377b	195.688b	527.77b	37.593b	3.116c	0.182c	569.46a
	Kernel Moisture (%)							
	20	0.392a	229.219a	604.23a	45.262a	4.056a	0.228a	489.86b
	30	0.364a	216.877b	583.94a	41.182b	3.743a	0.203b	494.90b
	40	0.363a	211.375b	579.03a	35.385c	3.243b	0.172c	539.44a

Different letters in the column section imply statistically significant differences at the significance level P=0.05

Table 3. Mean comparisons of the mechanical properties and electrical conductivity of corn kernels affected by drying methods

Dependent Variable	Drying method		t Statistic	Significant level
	Oven Drying	Sun drying		
Deformation (mm)	0.353	0.373	- 1.95	ns
Rupture force (N)	205.1	219.2	-2.84	**
Firmness (N mm^{-1})	586.2	599.1	- 0.87	ns
Energy required for kernels rupture (mJ)	36.8	40.61	- 2.03	*
Power required for kernels rupture (×10^{-3}W)	3.43	4.17	- 5.51	**
Toughness (mJ mm^{-3})	0.189	0.241	- 4.75	**
Electrical conductivity (µS/cm/g)	592.5	508.1	5.96	**

**-Significant at 1%level.*- Significant at 5%level.^{ns}- not Significant.

Rupture force

Result from the analysis of variance for data (Table 1) showed that effects of corn hybrid and moisture content at harvesting time on the force at the rupture point of the corn kernel in both drying methods were significant at 1% probability level. Results of the mean comparison of oven-dried kernels showed that the minimum and maximum rupture forces occurred for Konsur580 (183.560 N) and Jeta600 (217.799 N) hybrids, respectively (Table 2). In sun-dried grains, the maximum (233.083 N) and minimum (195.688 N) rupture forces belonged to Ns640 and Konsur580 hybrids, respectively (Table 2). The rupture force decreased in magnitude as the moisture of kernels at harvesting time increased in oven and sun drying methods (Table 2). Results of the mean comparison of rupture force at various moisture contents at harvesting time in oven and sun drying methods showed that the highest (221.295 N and 229.219 N) and the lowest (192.149 N and 211.375 N) values were linked to 20 and 40% moisture contents at harvesting time, respectively (Table 2). Interaction effects of the treatments (moisture content at harvesting time with corn hybrid) included no significant effects on the rupture force in the two drying methods (Table 1). The two-sided t-test results showed that effects of drying methods on the rupture force were significant and the highest value of rupture force (219.2 N) was seen in sun drying method (naturally dried kernels) (Table 3).

Firmness

Results from the variance analysis of data showed that effects of the corn hybrid on kernel firmness in oven and sun drying methods were significant at 5 and 1% probability levels, respectively (Table 1). The mean comparison results showed that Konsur580 hybrid in oven (523.37 N mm^{-1}) and sun (527.77 N mm^{-1}) drying methods

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included the lowest firmness within the four hybrids. Moreover, Sc704 hybrid included the highest firmness in oven (623.11 N mm^{-1}) and sun (625.44 N mm^{-1}) drying methods (Table 2). Although the moisture content at harvesting time included no significant effects on corn kernel firmness in the two methods of drying (p < 0.05), kernels harvested at 20% moisture included the highest firmness, compared to that kernels harvested at other moisture contents did (Table 2). The interaction effects of moisture content at harvesting time with corn hybrid in the two drying methods showed no significant effects on firmness. Results of the mean comparison (two-sided t-test) showed no significant differences between the corn kernel firmness levels in the two drying methods (Table 3).

The necessary energy for kernel rupture

Results from ANOVA of data showed that effects of both treatments of corn hybrid and moisture content at harvesting time on necessary energy for corn kernel rupture in both drying methods were significant at 1% probability level (Table 1). As shown in Table 2, Ns640 hybrid included the highest mean values of necessary rupture energy in oven (43.329 mJ) and sun (48.446 mJ) drying methods, compared to that other hybrids did (Table 2). From data in Table 2, necessary energy for the rupture of corn kernels decreased with increases in moisture contents at harvesting time. The mean comparison of data revealed that the least values of necessary rupture energy in oven drying (31.933 mJ) and sun drying (35.385 mJ) methods were linked to 40% moisture content at harvesting time (Table 2). The interaction effects of moisture content at harvesting time with corn hybrid on necessary energy for corn kernel rupture were not significant in the two drying methods (Table 1). Two-sided t-test results showed that effects of drying methods on necessary energy for corn kernel rupture were significant (p < 0.05) and the highest value of rupture energy (40.61 mJ) was seen in sun drying method (Table 3).

Necessary power for kernel rupture

Results from the variance analysis of data of necessary power for corn kernel rupture dried in oven indicated that corn hybrid and moisture content at harvesting time (independent variables) demonstrated significant effects on necessary power for corn kernel rupture at 1 and 5% significance levels, respectively. However, effects of treatments of corn hybrid and moisture content on necessary power were significant at 1% probability level in sun drying method (Table 1). Results of the mean comparison of necessary power for corn kernel rupture dried in oven showed that the maximum and minimum rupture powers were associated to Ns640 (3.858×10^{-3} W) and Konsur580 (3.042×10^{-3} W) hybrids, respectively. The maximum and minimum values of this property in sun drying method were linked to Ns640 hybrid with 4.300×10^{-3} W and Konsur580 hybrid with 3.116×10^{-3} W, respectively (Table 2). Results of the mean comparison of necessary power for corn kernel rupture at various levels of moisture content at harvesting time indicated that the highest values of rupture power in oven (3.706×10^{-3} W) and sun (4.056×10^{-3} W) drying methods were linked to 20% moisture at harvesting time. The interaction effects of moisture content at harvesting time with corn hybrid on necessary power for corn kernel rupture in the two drying methods were not significant (Table 1). Two-sided t-test results showed that effects of drying methods on necessary power for corn kernel rupture were significant (p < 0.01) and the highest rupture power (4.17×10^{-3} W) was seen in sun dried kernels (Table 3).

Toughness

Results showed that differences between the toughness levels of corn hybrids in oven and sun drying methods were significant at 1% probability level (Table 1). Corn kernels from Ns640 hybrid in oven (0.230 mJ/mm^3) and sun (0.241 mJ mm^{-3}) drying methods included the maximum toughness and kernels from Sc704 hybrid included the minimum values in oven (0.161 mJ mm^{-3}) and sun (0.172 mJ mm^{-3}) drying methods, compared to that the other hybrids did (Table 2). Effects of the moisture content of kernels at harvesting time on corn kernel toughness in oven and sun drying methods were significant at 5 and 1% probability levels, respectively (Table 1). Values of the kernel toughness decreased with increases in moisture content of kernels at harvesting time. In sun drying method, increases in moisture content of kernels at harvesting time from 20 to 40% significantly averagely decreased the corn kernel toughness from 0.228 to 0.172 mJ mm^{-3}. This data variation was from 0.219 to 0.166 mJ mm^{-3} in oven drying method (Table 2). The highest values of corn kernel toughness in oven (0.219 mJ mm^{-3}) and sun (0.228 mJ mm^{-3}) drying methods were associated to 20% moisture content at harvesting time. Interaction effects of the moisture content of kernels at harvesting time with corn hybrid in the two drying methods included no significant effects on corn kernel toughness. Results of the mean comparison (t-test) showed that effects of drying methods on the corn kernel toughness were significant (p < 0.01) and the sun drying method included the highest level of toughness (0.241 mJ mm^{-3}) (Table 3).

Electrical conductivity of the kernels

Results of the variance analysis of data showed that differences between the electrical conductivities of corn hybrids in oven and sun drying methods were significant at 1% probability level (Table 1). The mean comparison results showed that Konsur580 hybrid in oven (655.74 μs/cm/g) and sun (569.46 μs/cm/g) drying methods demonstrated the highest electrical conductivity within the four hybrids (Table 2). As shown in Table 1, effects of the

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moisture content of kernels at harvesting time in oven and sun drying methods on the electrical conductivity were significant at 1% probability level. Results from the mean comparison of electrical conductivity of corn kernels at various levels of moisture content at harvesting time revealed that the highest values of electrical conductivity in oven (628.62 µs/cm/g) and sun (539.4 µs/cm/g) drying methods were seen for 40% moisture content. The 20% moisture at harvesting time in oven dried (547.09 µs/cm/g) and sun dried (489.86 µs/cm/g) kernels included the lowest values of electrical conductivity (Table 2). Interaction effects of the corn hybrid with moisture content of kernels at harvesting time on electrical conductivity in oven drying method were significant at 5% probability level (Table 1) but not in sun drying method (Table 2). Mean comparison of the interaction effects of corn hybrid with moisture content of kernels at harvesting time in oven drying method showed that the highest level of electrical conductivity was correlated to Konsur580 hybrid with 40% moisture content of kernels (716.255 µs/cm/g) (Fig. 1). Results of the mean comparison (t-test) showed that effects of drying methods on the corn kernel electrical conductivity were significant (p < 0.01) and kernels dried in oven included the highest degree of electrical conductivity (592.50 µs/cm/g) (Table 3).

Discussion

In general, various corn hybrids in oven and sun drying methods demonstrated various rupture forces. Results from other studies showed that various corn hybrids included rupture forces (11). Rupture forces in magnitude decreased as the moisture of corn kernels at harvesting time increased in oven and sun drying methods. Higher moistures of the corn kernels at harvesting time decreased rupture forces and displacements at rupture points due to the increases in surface cracks resulted from high moisture evaporation during drying of the corn kernels. Peplinski et al. (24) reported that higher moisture contents at harvesting time increased the breakage susceptibility of corn grains. The highest value of the rupture force was linked to sun drying method (naturally dried kernels). A reason for decreasing rapture force with increasing drying temperature in oven drying method in comparison to sun drying method can be due to increases in the internal stress, which resulted in cracks in kernels damaging structure of the kernels. Effects of the corn hybrid in kernel firmness in oven and sun drying methods were significant. Konsur580 hybrid included the lower and Sc704 hybrid included the highest firmness values. Corn kernels harvested at 20% moisture included the highest firmness, compared to other moisture levels. Furthermore, Ns640 hybrid showed the highest mean values of the necessary rupture energy in oven and sun drying methods, compared to other hybrids. The necessary energy for the rupture of corn kernels decreased with increases in moisture content at the harvesting time. Delayed harvests provide plants with opportunities to complete grain filling stages and accumulate nutrients in grains. Thus, grains pass physiological maturity stages, including sufficient strengths of membranes and Testa. Effects of drying methods on necessary energy for the corn kernel rupture were significant with the highest value belonged to sun drying method. In a study by Maksoud (25), failure energy for the two corn varieties dried at room temperature reported as 64.5–85.4 mJ. These values included 35.38–45.26 mJ for kernels dried in sun with 40–20% of moisture contents in the present study.

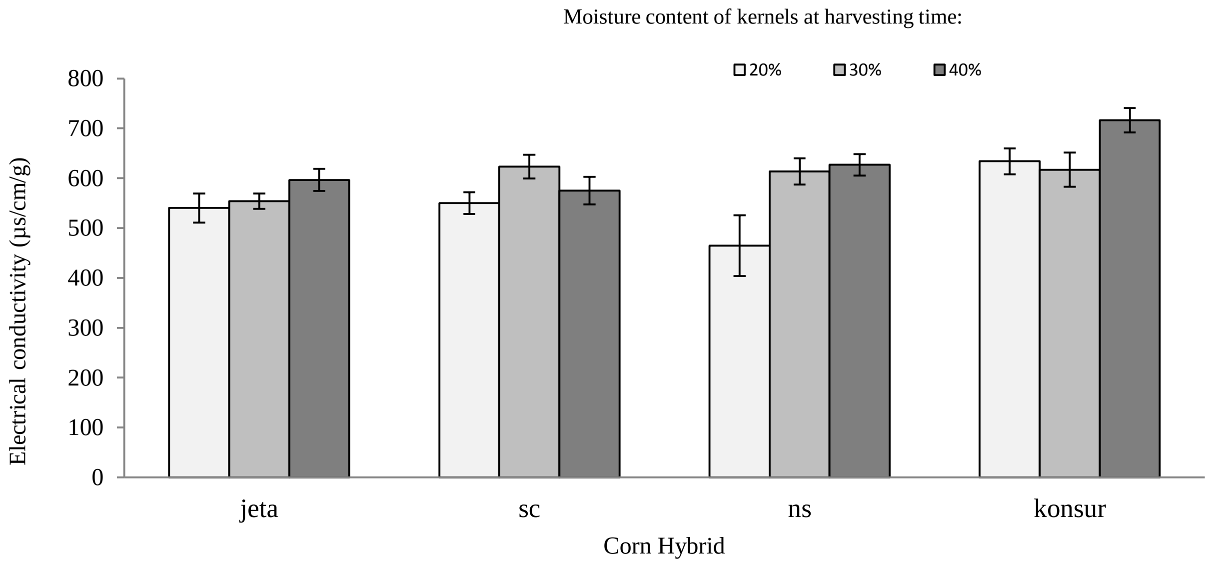

Figure. 1. Mean comparisons of electrical conductivity of corn kernels affected by corn hybrid and kernel moisture contents at harvesting time using oven drying method

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The highest values of rupture power were linked to 20% moisture at harvesting time. Due to the rapid evaporation of moisture from the inner layers of grains with high moisture contents during drying processes, stress cracks increased. Therefore, grains with higher moistures that were subjected to drying due to higher internal cracks needed lower rupture powers. Kernel toughness decreased with increases in moisture contents of the kernels at harvesting time. The highest corn kernel toughness was associated to 20% moisture content at harvesting time. At 40% moisture levels, hybrids have less thickness due to failures in completion of the grain storage. Hence, grains are thinner and more fragile. Moreover, grains have less toughness at 40% moisture levels due to the lack of full maturities of grains and incomplete membrane and testa structures. Effects of drying methods on corn kernel toughness were significant and sun drying method included the highest level of toughness. Similar results have been reported by Abasi and Minaei (26). Results indicated that the highest and the lowest electrical conductivities were linked to 40 and 20% moisture contents, respectively. These results showed that at 40% moisture content, emission of materials in cells was greater than that at 20 and 30% moisture contents due to the lack of full maturity of kernels and incomplete membrane and testa structures. It could generally be stated that delayed harvests decrease electrical conductivity of the seed extracts. This occurs due to complete ripening of the seeds at harvesting time and maturity of the cell membrane, which prevents leaking of the inner materials of seeds. A study by Durrant and Loads (27) showed that delayed harvesting of sugar beet seeds decreased electrical conductivity of the seed extracts.

Conclusion

Results of the present study showed that various corn hybrids included various reactions against the highlighted treatments [kernel moisture contents at harvesting time (20, 30 and 40%, wb) and drying methods (sun and oven drying methods)]. Moreover, harvesting of the corn kernels with lower moisture contents resulted in increases in strength and hardness of the kernels. From various levels of moisture contents at harvesting time and in terms of qualitative and mechanical properties, 20% moisture was reported as the best treatment. Dehydration of the corn kernels at high oven temperatures led to the emerging of stress crack and decrease of corn kernel quality. Moreover, results demonstrated that delayed harvests decreased electrical conductivity of the corn kernels. Therefore, selection of appropriate hybrids with ideal moisture contents at harvesting time and use of appropriate drying methods can be appropriate approaches to improve quality and mechanical properties of the corn kernels.

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