Effect of sheller rotational speed on some maize cultivars quality

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Abstract: The effect of rotational speed in sheller machine (LMS type) on maize cultivars of Cadiz (CA) and Golden (GO) were tested during sheller at three rotational speed of 300, 400 and 500 rpm. The experiments were carried out in a factorial experiment under complete randomized design with three replications. The results showed that the CA cultivar was significantly better than the GO in all studied conditions. The results showed a shelling productivity of 1.354 and 1.303 t h^{-1}, power consumption of 8.725 and 9.174 kW, shelling efficiency of 84.357% and 82.857%, unshelled grains of 1.260% and 1.509%, loose grains at kernel outlet of 1.444% and 1.612%, grains damage of 1.546% and 1.805% and grain cleanliness of 90.828% and 90.148% broken maize of 3.777% and 4.335% and cracked grain percentage of 2.674% and 3.066%, for CA and GO, respectively. The rotational speed of 300 rpm was significantly superior to the levels of 400 and 500 rpm in all studied conditions.

Keywords: mechanical damage, processed maize, maize, maize quality, shelling

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1 Introduction

Maize is considered important of crops it is now one of the most widely-grown crops around the world. Maize is grown both (as sweet maize) for human consumption and (as field maize) for other uses such as animal feed and biofuels. Worldwide, only around 15% of maize production is used for food consumption.

Shelling is the removal or separation of maize grain from the cob and it is an operation that follows the harvest. It can be carried out in the field or on the farm by hand or machines. The grain is obtained by shelling, friction or by shaking the products. The difficulty of the operation depends on the varieties grown, the moisture content and the degree of maturity of the crop. Maize is shelled traditionally by hands. This is done in such a way that maize is rubbed against another until the grains are removed from the cob. Shelling efficiency, cleaning efficiency, mechanical damage and percentage loss of a hand powered it can be deduced that the time of threshing has a negligible effect on the shelling efficiency of the machine. Similar trends were reported for the shelling efficiency of maize thresher with a shelling efficiency of 86% (Nwakaire et al., 2011),

A shelling unit for maize husker shelling was originally developed based on a wheat threshing unit, which was efficient but the grain breakage was relatively high (Chuan-Udom, 2013). The percentage of breakage grains and whole grain its related to the type of crop (Alwan et al., 2016). Maize shelling or simply maize threshing is the most important aspect of post-harvest operation of maize. Chilur et al. (2014) added that this operation is highly lab our intensive and more drudgery in addition to losses of grain in terms of quantity and quality. Salih and Arabhosseini et al. (2016) explained that there was a significant effect of the machine type and the moisture content on the energy consumption whenever the machine organization was desirable and lowest energy consumption. Increasing the machine rotational speed cylinder threshing causes a production increase in with rotational speed cylinder threshing of the machine is

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toward more automatic controls (Humburg, 2016). In this case, the operator is responsible for managing this important parameter. That decrease of the husk efficiency is due to blockage cavities of the machine at low clearance (Alsharifi et al., 2017b).

Threshing is the most important function of grain harvester (Fu et al., 2018). Grain loss and damage in harvesting are significantly related to threshing theory and technology. There are four kinds of threshing principles including impact, rubbing, combing and grinding, during removal of grains from the cobs. Tastra (2009) reported about the development of a new power sheller that could reduce grain damage and broken grains. Concave system that could vibrate without causing great impact on the maize grain. The performance evaluated that the machine is easy to operate with only the adjustment of roller clearance (Manjeet et al., 2017). The machine was found to have high dehulling and winnowing efficiencies at the optimum roller clearance. The sheller has a cleaning efficiency of 93%, 87% and 85% when shelling corn with a moisture content of 11%, 20% and 25% respectively, with a shelling unit speed of 400 rpm. Naveenkumar and Rajshekarappa (2012) reported that the capacity of sheller was found significantly different for each Sheller arrangement and speed combination at moisture contents. Higher capacity of shelling (402.01 kg h^{-1}) was found when maize having 13 per cent moisture fed to Sheller having cylinder rotating at a speed of 350 rpm. Maize production process using scientific technology methods for sheller process is give productively high by adopting modern technological methods to reduce the percentage of loss and increase profit, as also recommend works and other development works must do to introduce new technologies and increase perception of farmers and other users (Dawit, 2016). Pavasiya et al. (2018) having tested the performance of the fabricated machine, it could be concluded that the shelling efficiency, cleaning efficiency, grain recovery efficiency, Sheller performance index, total grain losses decrease and output capacit increased at 13% moisture contents of maize and at 886 rpm shelling speed. The best moisture content of maize for shelling (Aremu et al., 2015). Shelling efficiency, cleaning efficiency, grain recovery efficiency and output capacity were high which were at highest values at 13% moisture contents of maize and at 886rpm shelling speed. Thus, shelling of maize at 13% moisture content dry basis using 886 rpm shelling speed resulted into the highest efficiencies and capacity of the machine when compared with other moisture contents and shelling speeds.

The main goal of this research is to study the effect of shelling machine local maize shelling (LMS) on maize CA and GO cultivars at different rotational speeds.

2 Materials and methods

This study was conducted in 2017 to evaluate the performance of shelling machine (Local Maize Sheller. LMS). The experiments were done at three levels of rotational speed at levels of 300, 400 and 500 rpm. The Cadiz (CA) and Golden (GO) cultivars was selected for the experiments and the samples were taken by the probe and collected on the form of heap, which the number of heaps were six and each heap weight was 250 kg, according to the method used by (Alsharifi et al., 2017a). The maize samples were cleaned by using sieves to remove all foreign matters. Then the random samples which are taken from each heap in 500 kg. The initial moisture content of maize grain was determined by oven drying methods at 103°C for 48h (Alwan et al., 2016). The maize of CA and GO cultivars were kept in an oven at temperature of 43°C and monitored carefully for determining the moisture content of grain at 14%-16% then the samples were taken and placed in the precision divider to get a sample of 100 kg of cobs and then the samples were carefully sealed in polyethylene bags. power of Ac220v, Single -Phase required motor 5 Hp productivity 1500 kg h^{-1}, dimension 1026×471×990 mm, RPM 1800 r m^{-1} for lLMS (Figure 1). was adjusted on clearance between cylinder 0.6mm at rotational speed of 500 rpm and the samples of 100 kg of cobs were placed in the machine. Then the sample was taken out of the machine and placed in a cylindrical insulating device from a Satake type with operating time which was adjusted to 2 min. The angle of inclination was 25 degrees insolating the broken and full grain for all sizes. The shelling production, power consumption, shelling efficiency, cracked grain percentage, the breakage proportion, grain losses (unshelled grains percentage, loose grains at kernel outlet and grain damage) and percentage of grains cleanliness, were calculated for each running test.

2.1 Shelling productivity

The shelling productivity which depends on the type of the machine as well as the size and moisture content of the grain and efficiency of the machine, Equation (1) (Pavasiya et al., 2018)

$$P = \frac{W \times 60}{T \times 1000} \tag{1}$$

where, P is shelling productivity, t h^{-1}; W is output weight, kg and T is time, min.

2.2 Power consumption

Power consumption is the power, which is consumed by a machine to perform a specific job. The power consumption for this research was calculated by using Equation (2) (Alsharif, 2018)

$$P_W = \frac{\sqrt{3}}{1000} \cdot v \cdot I \cdot \cos\varphi \cdot E_{FE} \tag{2}$$

where, P_w is power consumed, kW; v is voltage, V; I is the electric current, A; cosφ is the angle between the current and voltage, and E_{FE} is the efficiency of the motor (90%).

2.3 Shelling efficiency

The Shelling efficiency was determined by using Equation (3) (Aremu et al., 2015)

$$E_E = \frac{W_S - W_{mU}}{W_S} \times 100 \tag{3}$$

where, E_E is the Shelling efficiency, % W_{mU} is the weight unsheller maize, g, and W_S is the weight of maize sample used, g.

2.4 Cracked grain

Cracks in the kernel are the most important factor contributing to maize breakage during threshing Equation (4) (Al Saadi and Al Ayoubi, 2012)

$$P_{Cg} = \frac{W_{Cg}}{W_S} \times 100 \tag{4}$$

where; P_{Cg} is proportion cracked grain, %, W_{Cg} is weight cracked grain, g, and W_S is the weight of maize sample used, g.

2.5 Breakage percentage

The Equation (5) was used to calculate the percentage of the whole grain and broken in the separation process of broken grain from the whole grains (Alwan et al., 2016)

$$P_{Br} = \frac{W_{Br}}{W_S} \times 100 \tag{5}$$

where, P_{Br} is the proportion of breakage, %; W_{br} is the weight of breakage grain, g, and W_s is the weight of maize sample used, g.

2.6 Grain losses

2.6.1 Unsheller grains percentage

After shelling operation, the unshelled grains from the cobs were shelled manually and weighted then unshelled grains percentage was determined by using Equation (6) (Metwally, 2010)

$$P_{LUN} = \frac{W_{UN}}{W_S} \times 100 \tag{6}$$

where, P_{LUN} is the losses unshelled grains, %; W_{UN} is the weight unsheller maize, g and W_S is the weight of maize sample used, g.

2.6.2 Loose grains at kernel outlet

The loose grains which found with the residual of cobs (kernel) were weighted was determined by using Equation (7) (Metwally, 2010)

$$P_{LKO} = \frac{W_K}{W_S} \times 100 \tag{7}$$

where, P_{LKO} is the losses grains at kernel outlet, %; W_K is the weight of grains with kernels, g, and W_S is the weight of maize sample used, g.

2.6.3 Grain damage

Equation (8) to determine the percentage of grain damage with weight the split and cracked grains were weighted (Chaudhary, 2016).

$$P_{GD} = \frac{W_{Sg}}{W_S} \times 100 \tag{8}$$

where, P_{GD} is the grain damage, %; W_{Sg} is the weight of split grains, g, and W_S is the weight of maize sample used, g.

2.6.4 Grain cleanliness

After threshing process a randomized of 1000 g grains were taken to calculated the percentage of grains cleaning, Equation (9) (Chaudhary, 2016)

$$G_C = \frac{W_S - W_I}{W_S} \times 100 \tag{9}$$

where, G_C is the percentage of grain cleanliness, %; W_S is weight of sample, g, and W_I is weight of impurities, g.

The same method was used with the same cultivars

(CA and GO) to test LCS type machine at grain moisture content in the range 14%-16%, and rotational speed of 300 and 400 rpm in three replications. The results were analyzed statistically using the complete randomized design CRD and for each factor the difference among treatments were tested according to the L.S.D test (Oehlent, 2010).

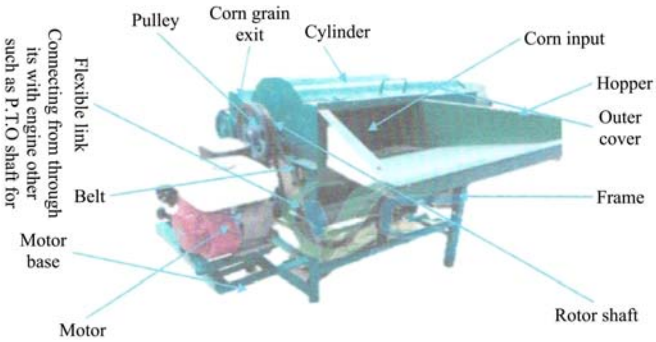

Figure 1 Machine (type Local Maize Sheller- LMS) used for sheller maize

3 Results and discussion

3.1 Shelling productivity

The influence of rotational speed on shelling productivity is shown in Table 1 for both CA and GO cultivars. The rotational speed at 500 rpm showed the highest shelling productivity of 1.396 Ton h^{-1}, while the lowest shelling productivity of 1.239 Ton h^{-1} was for 300 rpm rotational speed. Because the high pressure on the grain in the shelling chamber hence increase production process with increased rotational speed. These findings are consistent with the findings of (Naveenkumar and Rajshekarappa, 2012). It is indicated that the shelling productivity of the CA cultivar (1.354 t h^{-1}) is significantly better than GO cultivar (1.303 t h^{-1}). Due to the good qualities for the crop in shelled process. These results are consistent with the results of (Dawit, 2016). The level of the shelling productivity at different conditions is show in Figure 2 for both maize cultivars.

Table 1 The effect of rotational speed on shelling productivity for two maize cultivars

Cultivar	Rotational speed rpm			Means of cultivar
	300	400	500	
Cadiz	1.267	1.391	1.404	1.354
Golden	1.211	1.309	1.388	1.303
LSD=0.05				0.032
Means of rotational speed	1.239	1.350	1.396	
LSD=0.05		0.095		

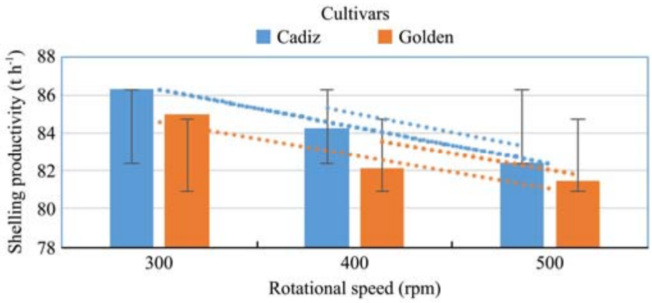

Figure 2 The effect of rotational speed on the shelling productivity for two maize cultivars

3.2 Power consumption

The influence of rotational speed on the power consumption kW. At rotational speed of 500 rpm has the lowest power consumption of 8.199 kW, and rotational speed 300 rpm has the highest power consumption of 9.665 kW. Because the increase in speed of the machine leads to decreasing machine disbursements and increased the breakage percentage. These results are consistent with the results of Humburg (2016). From Table 2, it is indicated that the power consumption of the CA cultivar (8.725 kW) is significantly better than GO cultivar (9.174 kW). These results are consistent with the results of (Alsharifi, 2018). The level of the power consumption at different conditions is show in Figure 3 for both maize cultivars.

Table 2 The effect of rotational speed on power consumption for two maize cultivars

Cultivar	Rotational speed rpm			Means of cultivar
	300	400	500	
Cadiz	9.116	8.967	8.091	8.725
Golden	10.214	9.001	8.306	9.174
LSD=0.05				0.521
Means of rotational speed	9.665	8.984	8.199	
LSD=0.05		0.108		

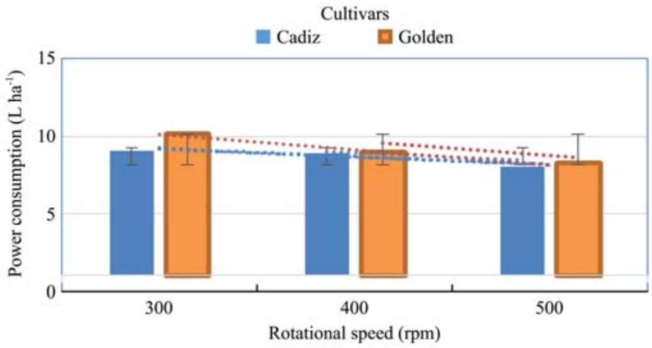

Figure 3 The effect of rotational speed on the power consumption for two maize cultivars

3.3 Shelling efficiency

The influence of rotational speed on shelling efficiency for both CA and GO cultivars is shown in Table 3. The rotational speed at 300 rpm showed the highest shelling efficiency of 85.697%, while the lowest shelling efficiency of 81.942% was for 500 rpm rotational speed. The increase of the shelling efficiency is due to blockage cavities of the machine at low rotational speed leads to obtain high shelling efficiency. These results are consistent with the results gained by Nwakaire et al. (2011). The CA cultivar (84.357%) was significantly better than the GO cultivar (82.857%). These results are consistent with the results of (Waree et al., 2016). The level of the shelling efficiency at different conditions is show in Figure 4 for both maize cultivars.

Table 3 The effect of rotational speed on shelling efficiency for two maize cultivars

Cultivar	Rotational speed rpm			Means of cultivar
	300	400	500	
Cadiz	86.371	84.266	82.435	84.357
Golden	85.022	82.101	81.449	82.857
LSD=0.05				0.671
Means of rotational speed	85.697	83.184	81.942	
LSD=0.05		0.892		

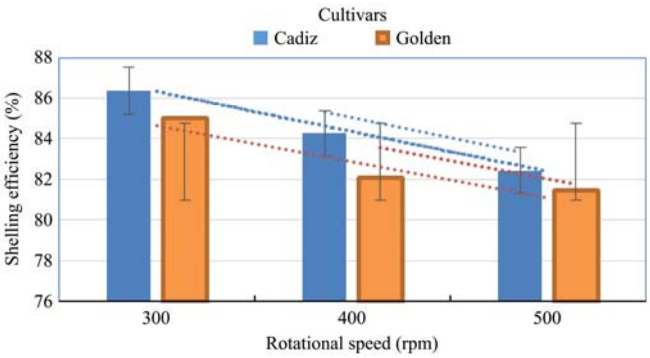

Figure 4 The effect of rotational speed on the shelling efficiency for two maize cultivars

3.4 Unshelled grains

The influence of rotational speed on the unshelled grains. At rotational speed of 300 rpm has the lowest unshelled grains of 1.101%, and rotational speed 500 rpm has the highest unshelled grains of 1.770%. From Table 4, it is indicated that the CA cultivar was significantly better than the GO cultivar. The results gained were 1.260% and 1.509% respectively. This is due to the crop quality to withstand the effort on grain during shelled process. These results are consistent with the results that gained by Metwally (2010). The unshelled grain is shown in Figure 5 at different conditions for both maize cultivars.

Table 4 The effect of rotational speed on unshelled grains for two maize cultivars

Cultivar	Rotational speed rpm			Means of cultivar
	300	400	500	
Cadiz	1.008	1.201	1.572	1.260
Golden	1.193	1.346	1.988	1.509
LSD=0.05				N.S
Means of rotational speed	1.101	1.273	1.770	
LSD=0.05		0.091		

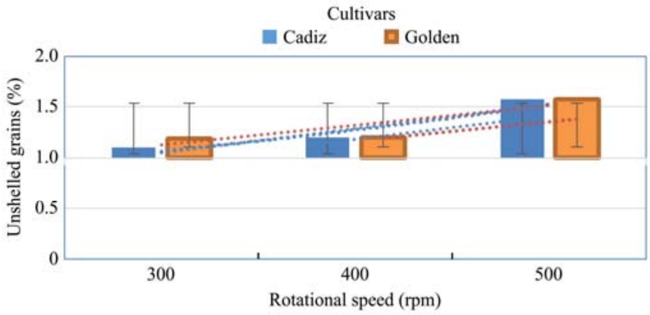

Figure 5 The effect of rotational speed on the unshelled efficiency for two maize cultivars

3.5 Loose grains at kernel outlet

The influence of the rotational speed loose grains at kernel outlet%. The results indicate that increasing the rotational speed leads to increase the loose grains at kernel outlet percentage, and the results were 1.156%, 1.478% and 1.952% respectively for different levels of rotational speed. Due to the mismatch between rotational speed and grain size (cobs) leads to increased percentage of loose grains at kernel outlet. These results are consistent with the results that gained by (Chilur et al., 2014). From Table 5, it is indicated that the CA cultivar was significantly better than the GO cultivar. The results gained were 1.444% and 1.612% respectively. This depends on grain size in shelling process. The level of the loose grains at kernel outlet at different conditions is show in Figure 6 for both maize cultivars.

Table 5 The effect of rotational speed on loose grains at kernel outlet for two maize cultivars

Cultivar	Rotational speed rpm			Means of cultivar
	300	400	500	
Cadiz	1.096	1.335	1.902	1.444
Golden	1.215	1.621	2.081	1.612
LSD=0.05				N.s
Means of rotational speed	1.156	1.478	1.952	
LSD=0.05		0.122		

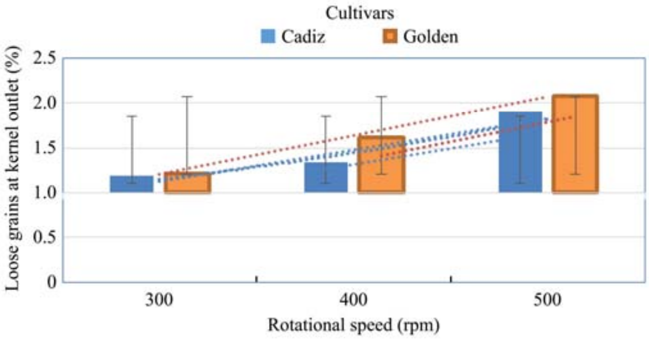

Figure 6 The effect of rotational speed on the loose grains at kernel outlet for two maize cultivars

3.6 Grain damage

The influence of rotational speed on the grain damage%. The results indicate that increasing the rotational speed leads to increase the grain damage percentage, and the results were 1.343%, 1.614% and 2.070% respectively for different levels of rotational speed. Because that there is not so much impact of blows when rotational speed decreased hence decreasing the grain damage percentage. These results are consistent with the results that gained by (Chilur et al., 2014). From Table 6, it is indicated that the CA cultivar was significantly better than the GO cultivar. The results gained were 1.546% and 1.805% respectively. This depends on grain size in shelling process. The grains damage is shown in Figure 7 at different conditions for both maize cultivars.

Table 6 The effect of rotational speed on grains damage for two maize cultivars

Cultivar	Rotational speed rpm			Means of cultivar
	300	400	500	
Cadiz	1.226	1.417	1.996	1.546
Golden	1.461	1.811	2.143	1.805
LSD=0.05				0.092
Means of rotational speed	1.343	1.614	2.070	
LSD=0.05		0.272		

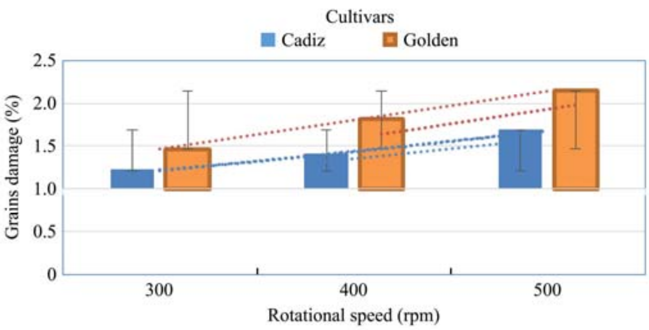

Figure 7 The effect of rotational speed on the grain damage for two maize cultivars

3.7 Cracked grain

The influence of rotational speed on percentage of cracked grain is shown in Table 7, for both CA and GO cultivars. The rotational speed at 500 rpm showed the highest cracked grain of 3.500%, while the lowest cracked grain of 2.102% was for 300 rpm rotational speed, because at higher rotational speed the pressure on the grain in the sheller chamber is higher and leads to increase the cracked grain percentage. These findings are consistent with the findings of (Salih et al., 2016). It is indicated that the cracked grain of the CA cultivar (2.674%) is significantly better than GO cultivar (3.049%). This is due to the crop quality and the machine organization during the shelling process. These results are consistent with the results of (Al Saadi and Al Ayoubi, 2012). The level of the cracked grain percentage at different conditions is show in Figure 8 for both maize cultivars.

Table 7 The effect of rotational speed on cracked grain at kernel outlet for two maize cultivars

Cultivar	Rotational speed rpm			Means of cultivar
	300	400	500	
Cadiz	2.021	2.991	3.011	2.674
Golden	2.133	3.026	3.988	3.049
LSD=0.05				0.123
Means of rotational speed	2.102	3.009	3.500	
LSD=0.05		0.341		

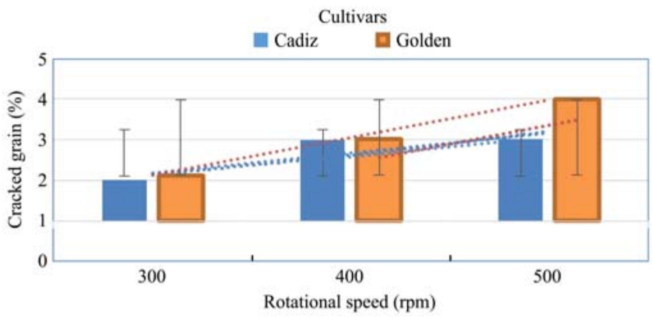

Figure 8 The effect of rotational speed on the cracked grain percentage for two maize cultivars

3.8 Broken maize

The influence of rotational speed on percentage of breakage maize is shown in Table 8, for both cultivars. The rotational speed at 500 rpm showed the highest broken maize of 4.664%, while the lowest broken maize of 3.463% was for 300 rpm rotational speed, because the ease grain flow leads to the decrease the proportion of breakage of grain, with decreased rotational speed. The results are similar to the result of Tastra (2009). It is indicated that the broken maize of the CA cultivar (3.777%) is significantly better than GO cultivar (4.335%). These results are consistent with the results of (Salih et al., 2016). The level of the breakage grain at different conditions is show in Figure 9 for both maize cultivars.

Table 8 The effect of rotational speed on breakage percentage for two maize cultivars

Cultivar	Rotational speed rpm			Means of cultivar
	300	400	500	
Cadiz	3.125	3.993	4.213	3.777
Golden	3.801	4.090	5.115	4.335
LSD=0.05				0.155
Means of rotational speed	3.463	4.042	4.664	
LSD=0.05		0.402		

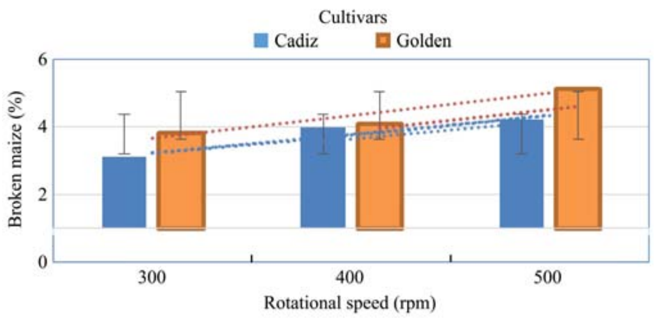

Figure 9 The effect of rotational speed on the breakage percentage for two maize cultivars

3.9 Grain cleanliness

The influence of rotational speed on the grain cleanliness (%) is shown in Table 9 for both cultivars. The results indicate that increasing the rotational speed leads to decrease the grain cleanliness, and the results were 91.066%, 90.410% and 89.998% respectively for different levels of rotational speed. This is due that the remove part of grain with impurities with increasing rotational speed hence grain cleanliness decreased. These results are consistent with the results that gained by (Chaudhary, 2016). It is indicated that the grain cleanliness of the CA cultivar (90.828%) is significantly better than GO cultivar (90.148%). This is due to the crop size (cobs) and the machine organization during the shelling process. This is consistent with (Pavasiya et al., 2018). The grain cleanliness is shown in Figure 10 at different conditions for both maize cultivars.

Table 9 The effect of rotational speed on grain cleanliness for two maize cultivars

Cultivar	Rotational speed rpm			Means of cultivar
	300	400	500	
Cadiz	91.601	90.816	90.066	90.828
Golden	90.531	90.003	89.911	90.148
LSD=0.05				0.149
Means of rotational speed	91.066	90.410	89.998	
LSD=0.05		0.182		

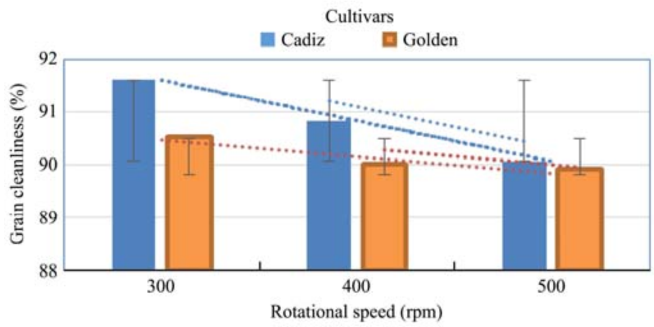

Figure 10 The effect of rotational speed on the grain cleanliness for two maize cultivars

4 Conclusion

The effect of rotational speed on mechanical damage of processed maize for two cultivars of CA and GO studied. The CA cultivar was significantly better than the GO cultivar in all studied conditions. The rotational of 300 rpm mm was significantly superior to the other two rotational speed of 400 and 500 rpm. The results showed better conditions for the overlap between the maize CA cultivar and 300 rpm rotational speed as compared to the overlap of the maize GO with other rotational speed. All the interactions were significantly different and the best results have come from the overlap between CA cultivar and 300 rpm in all studied conditions except shelling productivity and power consumption.

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