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Effect of threshing machines, rotational speed and grain moisture on corn shelling

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Abstract

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The effect of threshing machines on corn, Cadiz cultivar, was studied based on some technical indicators. Two types of machines (Local Corn Sheller 1 – LCS-Irs1 and Local Corn Sheller 2 – LCS-Irs2) were tested under three revolution of threshing cylinder 200, 300 and 400 rpm and three ranges of grain moistures of 16%, 18% and 20%. The experiments were carried out in a factorial experiment under complete randomized design with three replications. The results showed that LCS-Irs1 machine was significantly better than LCS-Irs2 machine in all studied conditions. The results showed a sheller productivity of 1.159 and 1.118 $t.h^{-1}$, power consumption of 11.142 and 11.913 kW, shelling efficiency of 81.753% and 80.953%, unshelled grains of 3.434 and 3.884%, loose grains at kernel outlet of 3.821 and 4.723%, grains damage of 1.994 and 2.225% and grain cleanliness of 89.694 and 89.170% for LCS-Irs1 and LCS-Irs2 machines, respectively. The rotational speed of 200 rpm was significantly superior to the other two levels of 300 and 400 rpm in all studied conditions, while the moisture content of grain at range of 16% was significantly superior to the other ranges of 18% and 20% in all studied conditions.

Keywords: corn; shelling; threshing machines; rotational speed; moisture content

Introduction

Corn is considered a promising option for diversifying agriculture in south areas of Iraq. It now ranks as the third most important food grain crop. The corn agriculture has slowly expanded during the past few years in Iraq that this area would grow further to meet future food, feed, and other demands, especially in view of the booming livestock and poultry producing sectors in the country. Since opportunities are limited for further expansion of maize area, future increases in maize supply will be achieved through the intensification and commercialization of current maize production systems. Corn shelling or simply maize threshing is the most important aspect of post-harvest operation of maize. The grains were detached from dried dehuked cobs by manual or mechanical device, which is known as shelling. This operation is highly labour intensive and more drudgery in addition to losses of grain in terms of quantity and quality (Chilur et al., 2014). That increase in moisture content causes a reduction in the friction coefficient between the grains with increase moisture content (Dziki, 2004). The machine productivity was so affected by the rotational speed cylinder threshing, as well as the moisture content of grain. Increasing moisture content lead to increase the breakage percentage and decrease the total productivity of the machine (Alwan et al., 2016b). El-Gayar (2005) studied the effect of flax thresher system partial mechanized complete and results were obtain that the unthreshed seed losses decreased by decreased seed moisture content. 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 corn grain. Hussain et al. (2009) carried out an investigation on the basic design of a corn shelling machine. He used a rotating shaft with threshing tooth on the surface to provide the shelling forces required. Corn shelling is defined as removal of grains from the cobs by the initial impact, and rubbing action as the material passes through a restricted clearance between the cylinder, and concave bars (Ayetigbo, 2001). Al Sharifi et al. (2017) 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 cause a production increase in with rotational speed cylinder threshing of the machine is toward more automatic controls. In this case, the operator is responsible for managing this important parameter. Humburg (2016) 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. Naveenkumar and Rajshekarappa (2012) have concluded that there was the influence of the machine type, clearance, moisture content on whole grain and the production process of machine, an increase clearance and decrease moisture led to increase production process and whole grain percentage. Alwan et al. (2016a) concluded that the minimum mechanical damage (3.1%) was obtained with the use of thresher with a speed of 600 rpm. This threshing speed resulted in good germination (81.4%) and seed purity (95.2%) (Kausal et al., 2003). Only the surface area and the kernel deformation are increasing with the increase of moisture content. Lupu et al. (2015) reported that the organizing of machine has a direct effect on the productivity of the machine. The better the machine is organized, the higher the productivity is because of the low percentage of break-up and this is reflected positively on the increase machine productivity due to increased efficiency of the existing work (Abu Al Khair et al., 2005). After threshing process the empty cobs will pass out through the cobs outlet opening and are thrown out by the force of rotation of the shelling discs, and then grain will spread through the grain outlet (Wanjala, 2014). It is explained that there was a significant effect of the machine type and moisture content on husking efficiency and concluded that increasing in the moisture content leads to decrease husking efficiency as well as decrease production process for machines used in the experiment (Alwan et al., 2018). The main goal of this research was to study the effect of sheller machines on maize specification under Local Corn Sheller – LCS-Irs1 and Local Corn Sheller – LCS-Irs2 at different rotational speed and different ranges of moisture grain content.

Materials and Methods

This study was conducted in 2017 to evaluate Local Corn Sheller – LCS-Irs1 and Local Corn Sheller – LCS-Irs2 threshing machines performance. The experiments were done at three levels of grain moisture contents of 16%, 18% and 20% and three rotational speeds at levels of 200, 300 and 400 rpm. The Cadiz cultivar was selected for the experiments and the samples were taken by the probe and collected on the form of heap. The heaps number were six and the mass of each heap was 250 kg. The random samples of maize are taken from each heap and they were cleaned by using sieves to remove all foreign matters. The initial moisture content of corn was determined by oven drying methods at 103°C for 48 h (Sacilik et al., 2003). The corn was kept in an oven at temperature of 43°C and monitored carefully for determining the moisture content of grain at 19%. The LCS-Irs1 type machine was adjusted on 0.6 mm clearance between cylinders and rotational speed of 400 rpm and then the samples were placed in the machine. After the end of threshing process by machine (LCS-Irs1 type) 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° insolating the broken and full grain for all sizes. The sheller productivity, power consumption, shelling efficiency, grain losses (unshelled grains percentage, loose grains at kernel outlet and grain damage) and percentage of grains cleanliness were calculated for each running test.

Moisture content of grain

Moisture content has a marked influence on all aspects of corn and it is essential that corn threshing milled at the proper moisture content to obtain the whole grain percentage no broken grains of corn. The moisture content of the sample was calculated by using Eq. 1 (Al Saidi, 1983):

$$W = \frac{W_w}{W_d} \times 100, \tag{1}$$

where, W is the moisture content of the grain (%), W_w is the wet weight, and W_d is the dry weight.

Rotational speed

Advice was used to calculate the number of rotations through sensitive the speed of rotation and is made of magnet and installed on the rotary engine. Then the engine and the magnet rotation will be counting the number of cycles, speed and time.

Sheller productivity

Basically, the thrashing machine productivity depends on the type of the machine as well as the size and moisture content of the grain and thrashing efficiency. It can be calculated from the Equation 1 that investigated by Al Sharifi et al. (2017) as follows:

$$P = \frac{W \times 60}{T \times 1000}, \tag{2}$$

where, P is sheller productivity (t/h), W is output weight (g), and T is time (min).

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 3 (Al Sharifi et al., 2016):

$$P = \frac{\sqrt{3}}{1000} \cdot U \cdot \mathrm{I} \cdot \cos \varphi \cdot E_{FE}, \tag{3}$$

where, P is power consumed (kW), U is voltage (V) and I is the electric current (A), cos φ is the angle between the current and voltage, and E is the efficiency of the motor (90%).

Threshing efficiency

The threshing efficiency is determined by using Equation 4 (Al Saadi and Al Ayoubi, 2012):

$$E_E = \frac{W_S - W_{mU}}{W_S} \times 100, \tag{4}$$

where: E_E is the threshing efficiency (%), W_{mU} is the weight of unsheller corn (g), and W_S is the weight of corn sample used (g).

Grain losses

Unsheller grains percentage

After shelling operation, the unshelled grains from the cobs are shelled manually and weighted then unshelled grains percentage is determined by using Equation 5 (Metwally, 2010).

$$P_{LUN} = \frac{W_{mU}}{W_S} \times 100, \tag{5}$$

where: P_{LUN} is the losses unshelled grains (%), W_{mU} is the weight unsheller corn (g), and W_S is the weight of corn sample used (g).

Loose grains at kernel outlet

The loose grains which was found with the residual of cobs (kernel) are weighted and was determined by using Equation 6 (Metwally, 2010):

$$P_{LKO} = \frac{W_k}{W_S} \times 100, \tag{6}$$

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 corn sample used (g).

Grain damage

Equation 7 was used to determine the percentage of grain damage with weight the split and cracked grains are weighted (Metwally, 2010):

$$P_{GD} = \frac{W_{Sg}}{W_S} \times 100, \tag{7}$$

where: P_{GD} is the grain damage (%), W_{Sg} is the weight of split grains (g), and W_S is the weight of corn sample used (g).

Grain cleanliness

After threshing process, a randomized of 1000 g grains are taken to calculated the percentage of grains cleaning, Equation 8 (Chaudhary, 2016).

$$G_C = \frac{W_S - W_I}{W_S} \times 100, \tag{7}$$

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

The same method was used with the same cultivar (Cadiz) to test the LCS-Irs1 type (Fig. 1) and LCS-Irs2 type (Fig. 2) machines at moisture grain content of 16% and 18% and rotation speeds of 200 and 300 rpm in three replications. The results were analyzed statistically using the complete randomized design (CRD) and the difference among treatments for each factor was tested according to the least significant difference (LSD) test (Alsahoeke and Creama, 1990).

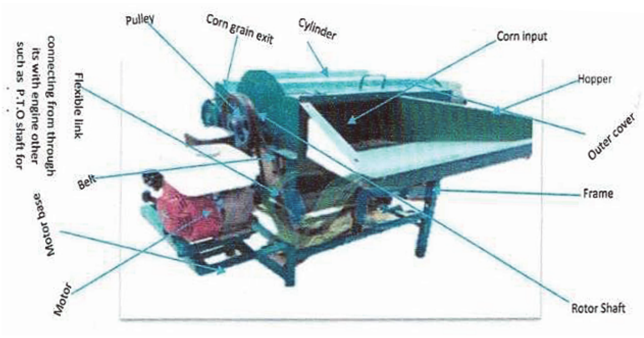

Fig. 1. Machine (type Local Corn Sheller LCS-Irs1) used for corn shelling

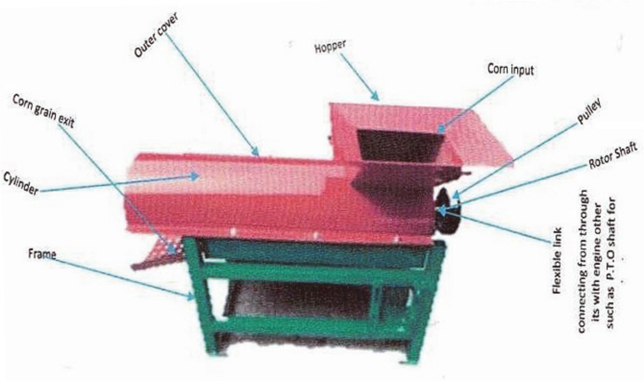

Fig. 2. Machine (type Local Corn Sheller LCS-Irs2) used for corn shelling

Two types of sheller machines (LCS-Irs1 and LCS-Irs2) were also used for experiments with different rotation speeds of 200, 300 and 400 rpm. The corn thresher machine LCS-Irs1 has the power of Ac 220 v, single-phase required motor 5 Hp, productivity 1500 kg h^{-1}, dimension 1026*471*990 mm, rate of revolution of a motor RPM 1800r m^{-1} and it can be operated using an internal combustion engine and electric motor is adopted in this experiment (Fig. 1). Corn thresher machine LCS-Irs2 has the power of Ac 220 v, 2.2 kw single-phase required motor 3 Hp, rate of revolution of a motor RPM 1800r m^{-1}, productivity 1000-1500 kg h^{-1}, dimension L*W 1100*400*870 mm (Fig. 2) .

Results and Discussion

Sheller productivity

Table 1 shows the influence of machine type, rotational speed and moisture grain on the Sheller productivity, t h^{-1}. The results indicated that increasing the rotational speed led to the increase of the sheller productivity, and the results were 0.986, 1.117 and 1.312 t h^{-1} respectively at different rotational speeds. This is due to the increased speed of the sheller cylinder that leads to increased sheller productivity with the increase of rotational speed. These results are consistent with the results gained by Hussain et al. (2009) who surveyed at different moisture contents. At the moisture content of 16% the highest sheller productivity of 1.207 ton\h was indicated and at the moisture content of 20% the lowest sheller productivity of 1.069ton\h was indicated. This is due to the fragility of the corn grains and adhesion in the cobs, this leads to decrease the sheller productivity with moisture content increased. This is consistent with El-Gayar (2005). However, LCS-Irs1 machine type was significantly better than LCS-Irs2 machine type and the results were 1.159 and 1.118 ton/h, respectively. This is

Table 1. The effect of machine type, grain moisture and rotational speed on sheller productivity, ton/h

The overlap between machines, grain moisture and rotational speed						
Machines		Grain moisture	Rotational speed, rpm			The overlap between machines and moisture
			200	300	400	
Local Corn Sheller LCS-Irs1		16%	1.012	1.214	1.456	1.227
		18%	1.006	1.131	1.303	1.146
		20%	0.997	1.042	1.267	1.102
Local Corn Sheller LCS-Irs2		16%	1.004	1.206	1.348	1.159
		18%	0.998	1.101	1.298	1.132
		20%	0.903	1.008	1.199	1.036
L.S.D. = 0.05			0.075			N.S
Average of rotational speed			0.986	1.117	1.312	
L.S.D. = 0.05			0.061			
Machines		The overlap between machines and rotational speed				Average of machines
Local Corn Sheller LCS-Irs1		1.005	1.129	1.342		1.159
Local Corn Sheller LCS-Irs2		0.968	1.105	1.282		1.118
L.S.D. = 0.05			N.S			0.056
Grain moisture	The overlap between grain moisture and rotational speed					Average of grain moisture
16%	1.008		1.210		1.402	1.207
18%	1.002		1.116		1.301	1.140
20%	0.950		1.025		1.233	1.069
L.S.D. = 0.05			0.101			0.061

Note: L.S.D. – Least Significant Difference

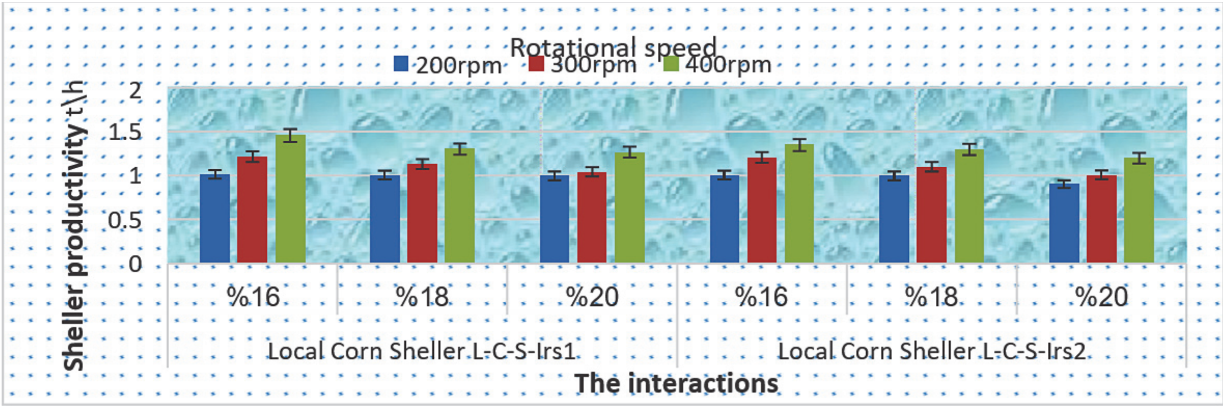

Fig. 3. Effect of rotational speed and grain moisture on the sheller productivity for two machines

due to the efficiency and engineering design of LCS-Irs1 machine and finishing the works with less time as compared with LCS-Irs1 machine type. These results are consistent with the results that are gained from Alwan et al. (2016a), who has established that at the interaction among parameters of LCS-Irs1 machine type, moisture content of 16% and the rotational speed of 400 rpm caused the best result of 1.456 ton/h. The sheller productivity is shown in Fig. 3 at different conditions for both machine types, moisture content and rotational speed.

Power consumption

The influence of machine type, rotational speed and moisture grain on the power consumption (kw), at rotational speed of 400 rpm has the lowest power consumption of 10.380 kw, and rotational speed 200 rpm has the highest power consumption of 12.662 kw. From Table 2 it is indicated that LCS-Irs1 machine type was significantly better than LCS-Irs2 machine type (11.142 and 11.913 kw, respectively). Because of high quality in carry out process

Table 2. The effect of machine type, grain moisture and rotational speed on power consumption, kw

The overlap between machines, grain moisture and rotational speed						
Machines		Grain moisture	Rotational speed, rpm			The overlap between machines and moisture
			200	300	400	
Local Corn Sheller LCS-Irs1		16%	10.892	9.234	8.309	9.478
		18%	12.706	11.661	10.207	11.491
		20%	13.552	12.635	11.081	12.422
Local Corn Sheller LCS-Irs2		16%	11.922	10.821	9.466	10.736
		18%	12.863	11.792	11.008	11.888
		20%	14.039	13.093	12.211	13.114
L.S.D. = 0.05			0.145			0.083
Average of rotational speed			12.662	11.539	10.380	
L.S.D. = 0.05			0.054			
Machines		The overlap between machines and rotational speed				Average of machines
Local Corn Sheller LCS-Irs1		12.383	11.177	9.866		11.142
Local Corn Sheller LCS-Irs2		12.941	11.902	10.895		11.913
L.S.D. = 0.05			0.083			0.076
Grain moisture		The overlap between grain moisture and rotational speed				Average of grain moisture
16%	11.407		10.028		8.888	10.108
18%	12.785		11.727		10.607	11.706
20%	13.796		12.864		11.646	12.769
L.S.D. = 0.05			0.112			0.054

Note: L.S.D. – Least Significant Difference

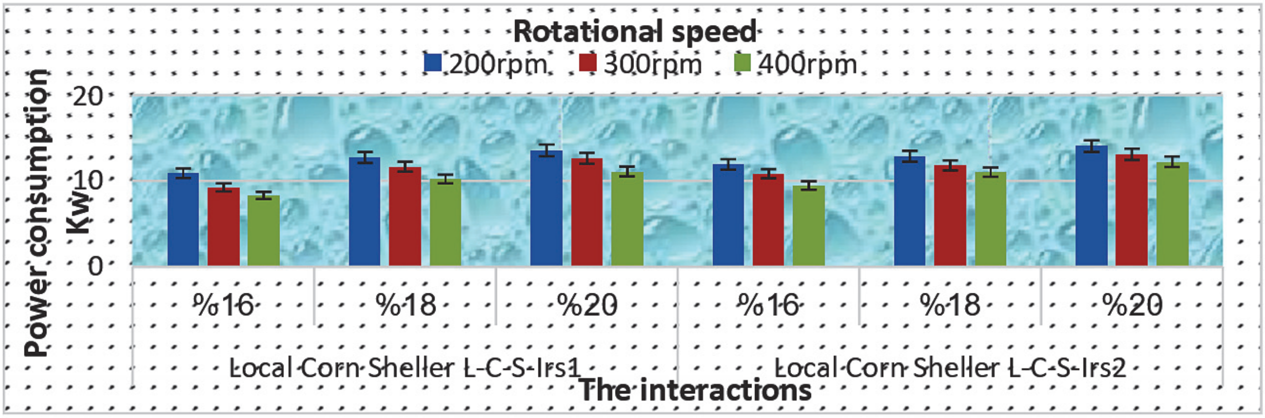

Fig. 4. Effect of rotational speed and grain moisture on the power consumption for two machines

sheller in less capacity consumed using LCS-Irs1 machine type as compared with LCS-Irs1 machine type. These results are consistent with the results gained from Alwan et al. (2018). As increasing the grain moisture leads to increase of the power consumption and the results were of 10.108, 11.706 and 12.769 kw respectively, at different grain moisture contents. This is due to the increased Damocles effort on grains during the sheller process hence increased the capacity consumed with the increasing moisture content of grain. This is consistent with Alwan et al. (2016a). The interaction among parameters of LCS-Irs1 machine type, moisture content of 16% and the rotational speed 400 rpm caused the best result of 8.309 kw. The power consumption is shown in Fig. 4 at different conditions for both machine types, moisture content and rotational speed.

Table 3. The effect of machine type, grain moisture and rotational speed on shelling efficiency, %

The overlap between machines, grain moisture and rotational speed						
Machines		Grain moisture	Rotational speed, rpm			The overlap between machines and moisture
			200	300	400	
Local Corn Sheller LCS-Irs1		16%	84.163	82.201	81.414	82.592
		18%	83.675	81.465	80.901	82.013
		20%	81.555	80.776	79.622	80.651
Local Corn Sheller LCS-Irs2		16%	83.445	82.160	81.211	81.938
		18%	81.909	80.968	79.415	80.764
		20%	80.966	79.826	78.675	79.822
L.S.D. = 0.05			0.458			0.322
Average of rotational speed			82.619	81.232	80.206	
L.S.D. = 0.05			0.231			
Machines		The overlap between machines and rotational speed				Average of machines
Local Corn Sheller LCS-Irs1		83.131	81.481	80.646		81.753
Local Corn Sheller LCS-Irs2		82.107	80.985	79.676		80.953
L.S.D. = 0.05			0.322			0.092
Grain moisture		The overlap between grain moisture and rotational speed				Average of grain moisture
16%	83.804		82.181		81.313	82.432
18%	82.792		81.217		80.158	81.389
20%	81.261		80.301		79.149	80.237
L.S.D. = 0.05			0.532			0.231

Note: L.S.D. – Least Significant Difference

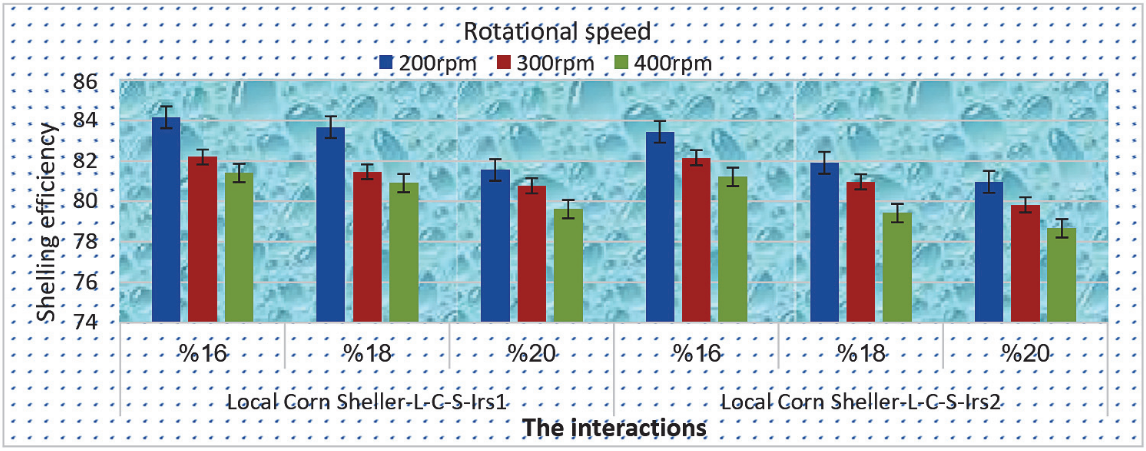

Fig. 5. Effect of rotational speed and grain moisture on the shelling efficiency for two machines

Shelling efficiency

The influence of machine type, rotational speed and moisture content on the shelling efficiency

At rotational speed of 200 rpm the shelling efficiency was highest (82.619%), and at rotational speed of 400 rpm the shelling efficiency was lowest (81.232%). This is due to the decrease breakage percentage by decreasing the rotational speed hence increased shelling efficiency. This is consistent with Humburg (2016). From Table 3 it is indicated that LCS-Irs1 machine type was significantly better than LCS-Irs2 machine type. The results were 81.753 and 80.953% respectively. Attributed to that the characteristics design of engineering which characterized by LCS-Irs1 machine type was compared with LCS-Irs2 machine type. These results are consistent with the results that gained by Al Saadi and

Table 4. The effect of machine type, grain moisture and rotational speed on unshelled grain, %

The overlap between machines, grain moisture and rotational speed						
Machines		Grain moisture	Rotational speed, rpm			The overlap between machines and moisture
			200	300	400	
Local Corn Sheller LCS-Irs1		16%	2.042	2.381	3.041	2.488
		18%	2.688	3.063	4.219	3.323
		20%	3.189	4.551	5.726	4.489
Local Corn Sheller LCS-Irs2		16%	2.909	3.002	3.502	3.138
		18%	3.077	3.692	4.312	3.693
		20%	3.694	4.865	5.904	4.821
L.S.D. = 0.05			0.125			N.S
Average of rotational speed			2.933	3.592	4.451	
L.S.D. = 0.05			0.213			
Machines		The overlap between machines and rotational speed				Average of machines
Local Corn Sheller LCS-Irs1		2.640	3.332	4.329		3.434
Local Corn Sheller LCS-Irs2		3.227	3.853	4.573		3.884
L.S.D. = 0.05			0.112			0.103
Grain moisture		The overlap between grain moisture and rotational speed				Average of grain moisture
16%	2.476		2.692		3.272	2.813
18%	2.882		3.378		4.266	3.509
20%	3.442		4.708		5.815	4.655
L.S.D. = 0.05			N.S			0.213

Note: L.S.D. – Least Significant Difference

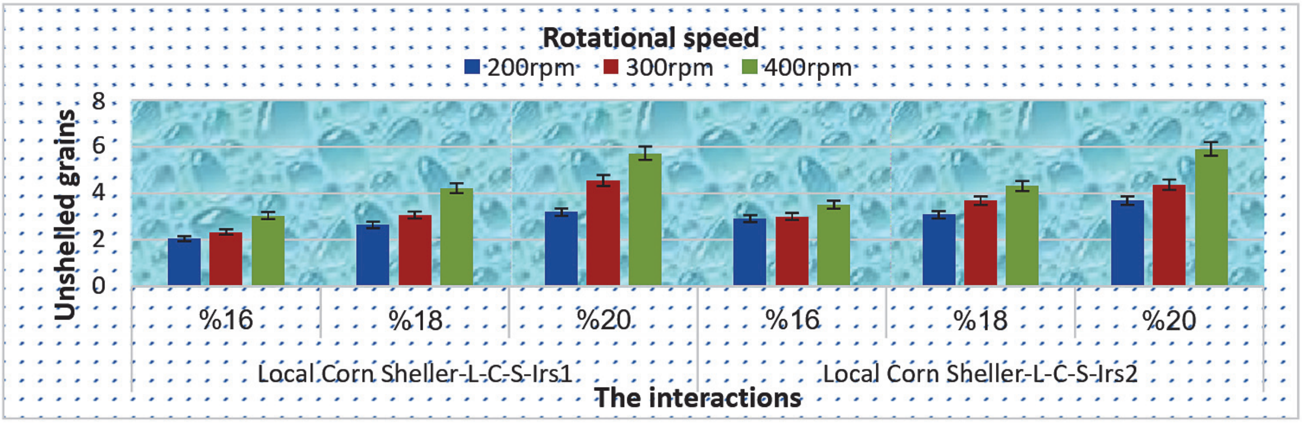

Fig. 6. Effect of rotational speed and grain moisture on the unshelled grains percentage for two machines

Al Ayoubi (2012). As for the increasing the grain moisture leads to decreasing of the shelling efficiency, the results were 82.432, 81.389 and 80.237% at different moisture content. This is due to the increase in moisture content of grain also leads to obstruct the shelling process hence decreasing shelling efficiency. This is consistent with Wanjala (2014). The interaction among parameters of LCS-Irs1 machine type, moisture content of 16% and the rotational speed of 200 rpm caused the best result of 84.163%. The shelling efficiency is shown in Fig. 5 at different conditions for both machine types, moisture content and rotational speed.

Unshelled grains

The influence of machine type, rotational speed and moisture grain on the unshelled grains

At rotational speed of 200 rpm the percentage of unshelled grains was the lowest (2.933%), and at rotational speed of 400 rpm it was highest (4.451%). From Table 4 it is indicated that LCS-Irs1 machine type was significantly better than LCS-Irs2 machine type (3.434 and 3.884%, respectively). Engineering design and efficient work-based during shelling process of the grain when using LCS-Irs1 machine type were compared to LCS-Irs2 machine type. These results are consistent with the results that gained by Al Sharifi et al. (2017). As increasing the grain moisture leads to increase of the unshelled grains and the results were of 2.813, 3.509 and 4.655% respectively, at different grain moisture. That moisture content increased in the field and the end use, grain may go through sheller operations leads to damage grains is the moisture content increased. This is consistent with Tastra (2009), according to whom the interaction among parameters of LCS-Irs1 machine type, moisture content of 16% and the rotational speed 200 rpm caused the best result of 8.309 kw. The unshelled grains are shown in Fig. 6 at different conditions for both machine types, moisture content and rotational speed.

Grain damage

Table 5 shows the influence of machine type, rotational speed and moisture grain on the grain damage percentage. The results indicated that increasing the rotational speed leads to increase the grain damage percentage, and the results were 1.668, 2.216 and 2.445% respectively for different levels of rotational speed. Because 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 were gained by Chilur et al. (2014) for different moisture contents. The lowest grain damage percentage (1.712%) was obtained at the moisture content of 16% and the highest grain damage percentage (2.606%) was obtained at the moisture content of 20%. When grain moisture increased, it leads to adhesion of the grains to the cobs resulted in grain damage with beating inside the machine. This is consistent with the results of Naveenkumar and Rajshekarappa (2012). However, LCS-Irs1machine type was significantly better than LCS-Irs2 machine type (1.994 and 2.225% respectively). Grain damage is due to mechanical damage through shelled process using LCS-Irs1machine type as compared to LCS-Irs2 machine type. Abu Al Khair et al. (2005) has established that the interaction among parameters of LCS-Irs1 machine type, moisture content of 16% and the rotational speed 200 rpm caused the best result (1.091%). The grain damage percentage is shown in Fig. 7 at different conditions for both machine types, moisture content and rotational speed.

Table 5. The effect of machine type, grain moisture and rotational speed on grain damage, %

The overlap between machines, grain moisture and rotational speed						
Machines		Grain moisture	Rotational speed, rpm			The overlap between machines and moisture
			200	300	400	
Local Corn Sheller LCS-Irs1		16%	1.091	1.812	1.913	1.605
		18%	1.483	2.032	2.104	1.873
		20%	1.999	2.676	3.001	2.505
Local Corn Sheller LCS-Irs2		16%	1.441	1.986	2.030	1.819
		18%	1.987	2.009	2.455	2.150
		20%	2.011	2.940	3.166	2.706
L.S.D. = 0.05			N.S			N.S
Average of rotational speed			1.668	2.216	2.445	
L.S.D. = 0.05			0.123			
Machines		The overlap between machines and rotational speed				Average of machines
Local Corn Sheller LCS-Irs1		1.524	2.120	2.339		1.994
Local Corn Sheller LCS-Irs2		1.813	2.312	2.550		2.225
L.S.D. = 0.05			N.S			0.106
Grain moisture		The overlap between grain moisture and rotational speed				Average of grain moisture
16%	1.266		1.899		1.972	1.712
18%	1.735		2.021		2.280	2.012
20%	2.005		2.728		3.084	2.606
L.S.D. = 0.05			0.201			0.123

Note: L.S.D. – Least Significant Difference

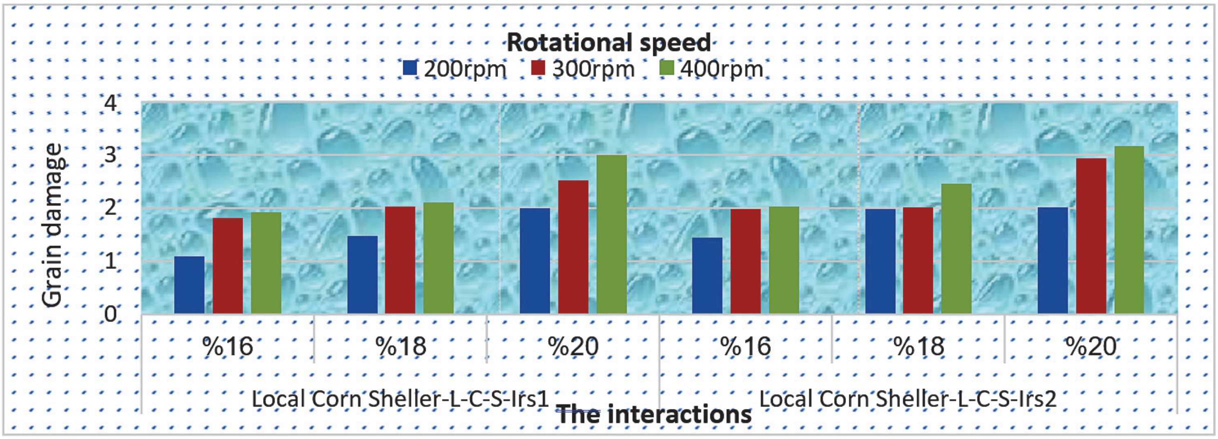

Fig. 7. Effect of rotational speed and grain moisture on the grain damage percentage for two machines

Loose grains at kernel outlet

The percentage of loose grains at kernel outlet was affected by the influence of machine type, rotational speed and moisture grain showed in Table 6 which is indicated that LCS-Irs1 machine type was significantly better than LCS-Irs2 machine type, the results were 3.821 and 4.723% respectively. This is due to the way the machine works as well as how it deal with grain when shelling process of LCS-Irs1 machine type is compared with LCS-Irs2 machine type. These results are consistent with the results gained by Kausal et al. (2003). The lowest percentage (3.242%) of loose grains at kernel outlet was obtained at rotational speed of 200 rpm and the highest percentage (4.939%) of loose grains at kernel outlet was obtained at rotational speed of 400 rpm. The increased percentage of loose grains

Table 6. The effect of machine type, grain moisture and rotational speed on loose grains at kernel outlet, %

The overlap between machines, grain moisture and rotational speed						
Machines		Grain moisture	Rotational speed, rpm			The overlap between machines and moisture
			200	300	400	
Local Corn Sheller LCS-Irs1		16%	2.443	3.811	4.082	3.445
		18%	2.997	3.902	4.876	3.925
		20%	3.082	4.131	5.068	4.093
Local Corn Sheller LCS-Irs2		16%	3.053	3.778	4.067	3.632
		18%	3.822	4.210	5.715	4.582
		20%	4.055	4.935	5.826	4.938
L.S.D. = 0.05			0.113			0.056
Average of rotational speed			3.242	4.129	4.939	
L.S.D. = 0.05			0.038			
Machines		The overlap between machines and rotational speed				Average of machines
Local Corn Sheller LCS-Irs1		2.840	3.948	4.675		3.821
Local Corn Sheller LCS-Irs2		3.643	4.307	5.202		4.723
L.S.D. = 0.05			0.056			0.024
Grain moisture		The overlap between grain moisture and rotational speed				Average of grain moisture
16%	2.748		3.795		4.075	3.873
18%	3.410		4.056		5.296	4.254
20%	3.569		4.533		5.447	4.516
L.S.D. = 0.05			0.109			0.038

Note: L.S.D. – Least Significant Difference

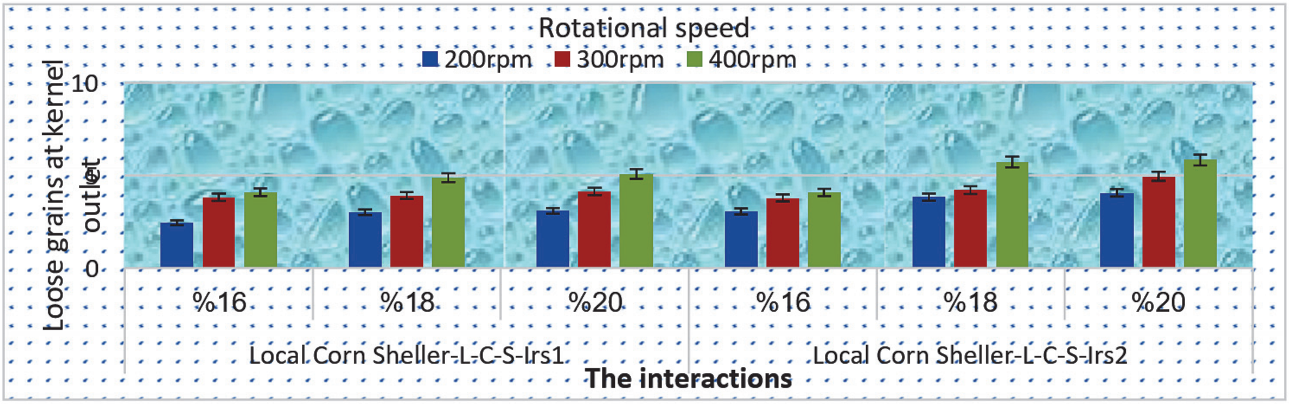

Fig. 8. Effect of rotational speed and grain moisture on the loose grains at kernel outlet for two machines

at kernel outlet is due to the mismatch between rotational speed and grain size (cobs) on the one hand and machine type on the other hand. These results are consistent with the results of Al Sharifi et al. (2016). The increasing the grain moisture leads to increasing of the loose grains at kernel outlet percentage and the results were 3.873, 4.254 and 4.516% respectively, at different grain moisture. This is due to the fragility of the grain and easily damage it when increased moisture of grain during shelling stage and increased percentage of loose grains at kernel outlet. This is consistent with Dziki (2004). The interaction among parameters of LCS-Irs1 machine type, moisture content of 16% and the rotational speed of 200 rpm caused the best result of 2.443%. The percentage of loose grains at kernel outlet is shown in Fig. 8 at different conditions for both machine types, moisture content and rotational speed.

Grain cleanliness

Table 7 shows the influence of machine type, rotational speed and moisture of the grain on the grain cleanliness (%). The results indicate that increasing the rotational speed leads to decrease the grain cleanliness, and the results were 90.561, 89.190 and 88.545% respectively for different levels of rotational speed. This is due to the removing of part of the grain with impurities with increasing rotational speed hence grain cleanliness decreased. These results are consistent with the results that gained by El-Gayar (2005). The highest grain cleanliness (90.658%) was obtained at the moisture content of 16% and the lowest grain cleanliness (88.351%) was obtained at the moisture content of 20%, because increased straw with increasing grain moisture leads to grain cleanliness decrease. These results are consistent with Lupu et al. (2015). However, the LCS-Irs1 machine type was significantly better than the LCS-Irs2 machine type and the

Table 7. The effect of machine type, grain moisture and rotational speed on grain cleanliness, %

The overlap between machines, grain moisture and rotational speed						
Machines		Grain moisture	Rotational speed, rpm			The overlap between machines and moisture
			200	300	400	
Local Corn Sheller LCS-Irs1		16%	92.781	90.146	90.006	90.978
		18%	90.185	89.213	88.462	89.287
		20%	89.988	88.562	87.902	88.817
Local Corn Sheller LCS-Irs2		16%	91.314	90.008	89.696	90.339
		18%	90.001	89.077	88.173	89.084
		20%	89.095	88.131	87.033	88.099
L.S.D. = 0.05			N.S			0.208
Average of rotational speed			90.561	89.190	88.545	
L.S.D. = 0.05			0.223			
Machines		The overlap between machines and rotational speed				Average of machines
Local Corn Sheller LCS-Irs1		90.985	89.307	88.790		89.694
Local Corn Sheller LCS-Irs2		90.137	89.072	88.301		89.170
L.S.D. = 0.05			0.208			0.076
Grain moisture		The overlap between grain moisture and rotational speed				Average of grain moisture
16%	92.048		90.075		89.851	90.658
18%	90.093		89.145		88.318	89.185
20%	89.542		88.347		87.468	88.451
L.S.D. = 0.05			0.312			0.223

Note: L.S.D. – Least Significant Difference

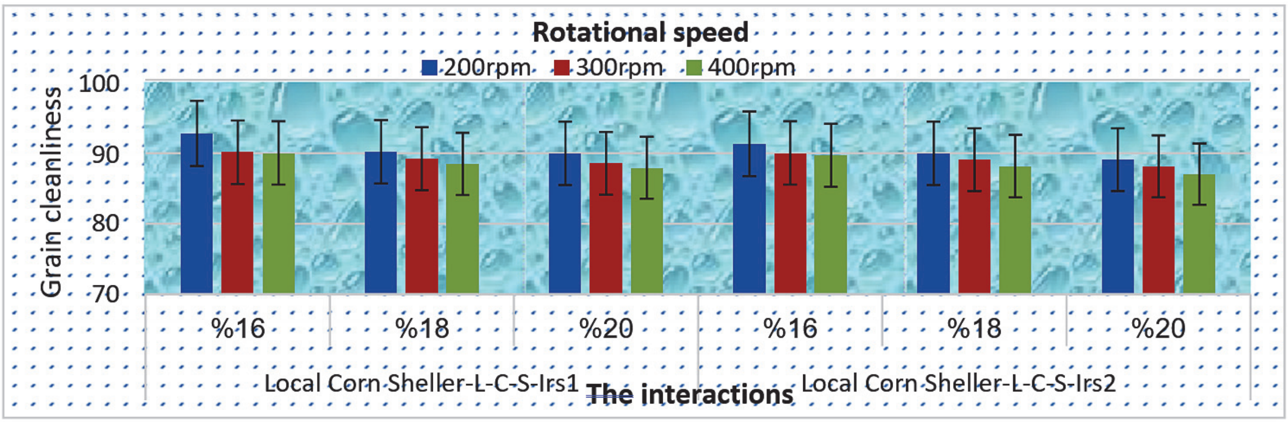

Fig. 9. Effect of rotational speed and grain moisture on the grain cleanliness percentage for two machines

results were 89.694 and 89.170% respectively. Because of high quality in thresher process, less capacity when LCS-Irs1 machine type was used to compare with LCS-Irs2 machine type, hence decreased grain cleanliness percentage (Chaudhary, 2016). The interaction among parameters of LCS-Irs1 machine type, moisture content of 16% and the rotational speed 200 rpm caused the best result of 92.781%. The grain cleanliness is shown in Fig. 9 at different conditions for both machine types, moisture content and rotational speed.

Conclusions

The LCS-Irs1 machine type is significantly better than the LCS-Irs2 machine type. The grain moisture content 16% was superior significantly on than the other two levels 18% and 20%. Additional, the rotational speed of 200 rpm was superior significantly on than the other two speeds 300, 400 rpm in all studied properties. The overlap between the LCS-Irs1 machine type and moisture content 16% was also superior significantly. The overlap between the LCS-Irs1 machine type and the rotational speed was 200 rpm, as compared with the overlap of the LCS-Irs2 machine type with moisture content and rotational speed in all studied properties. The best results have come from the triple overlap between LCS-Irs1 machine type, grain moisture 16%, and rotational speed of 200 rpm in some studied properties unshelled grains (loose grains at kernel outlet and grain damage) shelling efficiency and grain cleanliness except for sheller productivity and power consumption which best results was recorded with rotational speed 400 rpm.

Recommendations

The present study recommends to carry out future studies using other machinery types and other varieties of corn, to conduct other organizations on machine and the moisture content of grain to know their effect on the qualitative characteristics of corn.

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