Journal of Research in Ecology

An International Scientific Research Journal

ISSN No: Print: 2319 –1546; Online: 2319– 1554

Original Research

Studying and evaluating the performance of locally fabricated and developed maize sheller

Authors:
Ali Mohammed Ali[1], Ahmed Akbar Ali[1] and Basim Aboud Abbas[2]

Institution:
1. Department of Agricultural Machines and Equipment, College of Agriculture, University of Baghdad, Iraq.

2. Department of Animal Production, College of Agriculture, University of Diyala, Iraq.

Corresponding author:
Basim Aboud Abbas

ABSTRACT:

A corn sheller machine was fabricated and developed locally, which comprised of a shelling cylinder and a central longitudinal shaft located inside, whereby threshing chains are also attached. Multiple openings in the machine were made: inlet for entering the corns/kernels, grain outlet, and cobs outlet. A sieve is placed downward for separating grains out of its cobs. The machine is powered by an electric motor, along with different rotational speed alternatives, gained by changing belts and pulley sizes. The sheller was evaluated by changing shelling time, from 30 to 40 sec, along with diverse rotational speeds of 270, 470 and 670 rpm, and various machine feeding rates of 4, 7 and 10 kg. Using factorial experiment according to the Complete Randomized Design (CRD), and Least Significant Difference (LSD) to test the means, the experiment was conducted at the probability of 0.05, with three replications. The results showed that the time of shelling effected significantly on the shelling ratio, shelling efficiency and unshelled grains, whereas it didn't influence significantly on the power consumed and broken grains. Changing the rotational speed and machine feeding rate led to a significant effect on the shelling ratio, power consumed, shelling efficiency, unshelled grains and broken grains. The combination of shelling time (30 sec), speed of 470 rpm and weight of 10 kg recorded the best indicators that can be relied on and considered to be credential in the test.

Keywords:

Corn sheller, Shelling, Corn shelling, Corn thresher.

Article Citation:
Ali Mohammed Ali, Ahmed Akbar Ali and Basim Aboud Abbas
Studying and evaluating the performance of locally fabricated and developed maize sheller
Journal of Research in Ecology (2018) 6(2): 1822-1831

Dates:
Received: 09 June 2018 **Accepted:** 06 July 2018 **Published:** 04 Aug 2018

Web Address:
http://ecologyresearch.info/documents/EC0585.pdf

Journal of Research in Ecology

INTRODUCTION

Corn is considered to be among the most important crops around the world because of its role in the agricultural economy. Corn is also known as the queen of cereal and King of fodder, due to its big role after rice and wheat, in human's and animal's food (llori *et al*., 2013; Patil *et al*., 2016; Mali *et al*., 2016) mentioned through comprehensive-investigational studies, that the corn was used widely all over the world. Where, it's being shelled by different machines. Adewole *et al*. (2015) stated that among the primary processes after harvesting corn is separating grains out of the cobs and is known as shelling or threshing. Vinay (2016) defined shelling as separating or removing the seeds out of the cobs, in a process that is performed in the field after harvesting, manually or by using suitable machines depending on the friction force or shaking the cobs. Udom (2013) mentioned that shelling corn is considered among the productive processes, because it makes manufacturing transportation and storing easier. Threshing or shelling mechanism is the most important one on the machine that affects the consumed power and productivity, as well as engine rotational speed and machine feeding rate. James *et al*. (2011) concluded that increasing the shelling speed led to increasing the productivity, broken grains, and consumed power, along with decreasing unshelled grains. Naveenkumar (2011) stated that it's necessary to adjust the speed of the shelling unit along with the provided corn. Azeez *et al*. (2017) mentioned that increasing time of shelling led to an increase in the amount of the shelled grains, thus led to a decrease in the unshelled grains. In a study conducted by Abagissa and Befikadu (2015) reported that the appropriate adjusting for the corn sheller can give a ratio of shelling of 100% without any losses. The present research aims to fabricate and develop a mechanical shelling machine, to reduce the losses amount and damaged seeds or grains, test and evaluate the performance of the sheller fabricated locally.

MATERIALS AND METHODS

Device manufacturing

An experiment was conducted in the mechanical Workshop of the Department of Agricultural Machines and Equipment - College of Agriculture - University of Baghdad. After all the schemes and charts were placed, a corn sheller was fabricated locally in a local workshop to test its performance and efficiency, as illustrated in Figure 1. The sheller is composed of a threshing cylinder (1), an inlet (2) is attached to it and used for feeding the machine with kernels, the inlet is equipped with a gate for precision sealing. The cylinder has two other openings, (3), one in the front equipped with a floor that is slopped, which is designed to help the seeds roll over and fall out easily into a bag or any available container. The other opening is an outlet for the cobs (4) and is located at the end of the threshing cylinder and equipped with a gate to control the exact moment of letting the cobs get out. A central shaft is located longitudinally inside the cylinder (5), with a number of chains whereby are attached to it (8). The shaft is powered with an electric motor (6) through pulleys and belts (7) that can be altered to choose the suitable speed. The metallic chains do the job of shelling corns, whereby the kernels are being hit with those metallic chains and then the seeds are extracted and fall afterwards into a sieved floor (9). This feature distinguishes this design from the conventional threshers that are equipped with hammers or threshing drums. The sheller stands on a metallic frame (10), equipped with wheels (11) for the ease of movement of the thresher from one place to another by the help of two push handles (12), which are equipped with hinge joints for folding, in the case of being steady and ready for threshing. The control of threshing / shelling shaft was done by changing the pulley and the corresponding belt, as illustrated in the Table 1.

Test

To test the sheller, one ton of Iraqi yellow corn (maize) was bought from the local market, with a

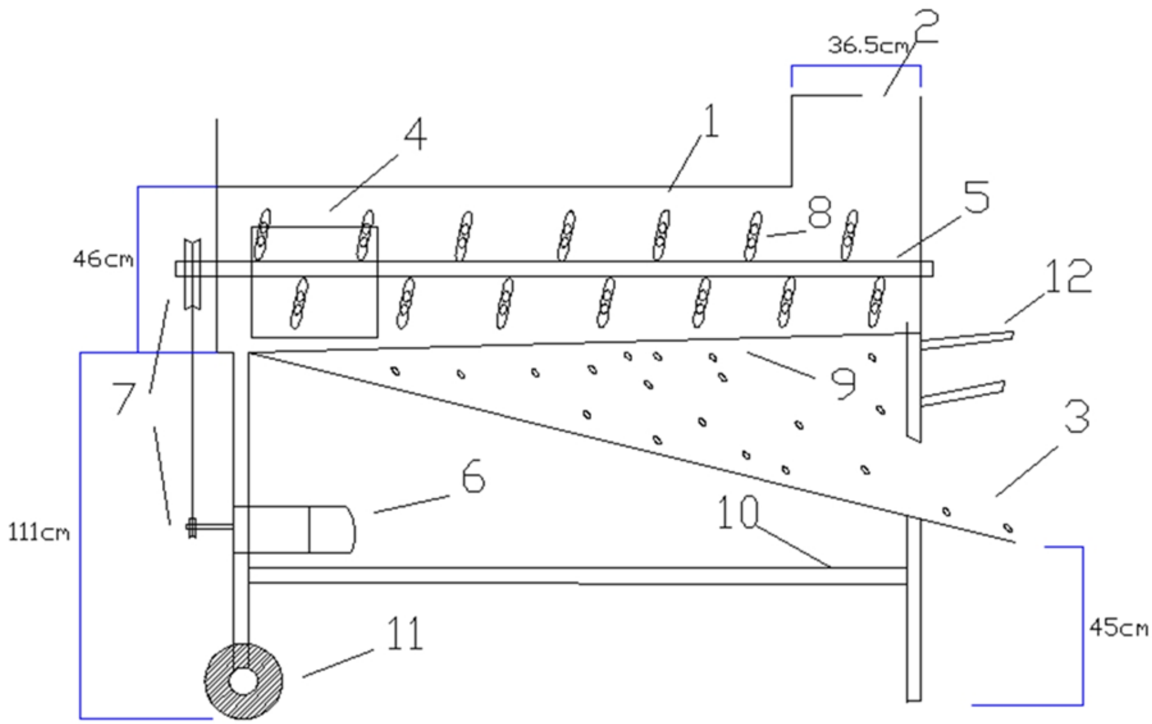

Figure 1. The fabricated and developed sheller

1: Shelling cylinder; 2: Kernel inlet; 3: Corn seeds outlet; 4: Cobs outlet; 5: Rotating shaft; 6: Electrical engine; 7: Pulleys and belts; 8: Iron chains; 9: Sieves; 10: Threshing frame; 11: Ground wheel; 12: Handle for moving the machine around

moister of (7%) that was determined using an electronic device specially designed for seeds moisture measuring. Different weights of corn samples were used for inserting into the machine. The speed of the threshing shaft was measured using a laser speed device. Threshing time was measured manually by a digital clock. The test was conducted after controlling the following variables:

1. Time of shelling in two levels, 30 and 40 sec.
2. Speed of shelling in three levels, 270, 470, and 670 revolutions per min.
3. Weight of the machine's feeding with kernels in three levels *viz:* 4, 7 and 10 kg.

Table 1. The measurements of the sheller that is fabricated locally

S. No	Measurements	Values
1	Length of the threshing cylinder	100 cm
2	Diameter of the threshing cylinder	46 cm
3	Number of threshing chains	18 cm
4	Distance between one chain and another	10 cm
5	Width X length of the cobs outlet	26.5 x 26.5 cm
6	Distance between the engine pulley and the shaft	42.5 cm
7	Engine pulley diameter	7 cm
8	Driven pulley (1) diameter	15.5 cm
9	Driven pulley (2) diameter	22.5 cm
10	Driven pulley (3) diameter	28 cm
11	Engine speed	1420 rpm

In three replications for the total figure of 54 replications, the treatments were analyzed by using (SAS, 2004) according to the Complete Randomized Design (CRD), the significance of the factors was tested according to the Least Significance Design (LSD) at a probability of 0.05, and the studied indicators and their formulas were as follows:

Shelling rate (kg/h)

When the seeds are collected after being separated from the cobs in a certain time, the shelling time is determined according to the following formula given by Bako and Boman (2017) :

$$\text{Shelling rate} = \frac{\text{Weight of shelled grains (kg)}}{\text{Time (h)}} \quad (1)$$

Power consumption (KW)

Power consumption was determined by using a clamp meter to gauge the electrical current change during conducting the treatment process, the consumed power was determined according to Payne (1997) :

$$P=IX(V*1.73*PF/1000) \ldots \quad (2)$$

where, P: Consumed power (kilowatt); I: Electrical current (ampere); V: Voltage (volt); PF: Power factor (if unknown, supposed to equal 0.93).

Shelling efficiency (%)

Shelling efficiency was measured as a percentage by weighing the amount of the unshelled seeds from kernels in relation to the total shelled seeds, then the division result is subtracted from 100 according to the following formula given by Al- Desouky *et al*. (2007) :

$$\text{Shelling efficiency} = 100 - \frac{\text{Weight of unshelled grains}}{\text{Total weight of shelled grains}} \quad (3)$$

Unshelled grains (%)

Unshelled grains were measured by weighing the amount of unshelled seeds in relation to the weight of the total shelled grains/seeds, and then the result was regarded as percentage according to the following formula given by Vinay (2016):

Table 2. Effect of time, shelling speed and machine feeding rate on the shelling rate (kg/h)

Threshing time (s)	Threshing speed (rpm)	Machine feeding rate (kg/h)			Effect of mean Time * speed
		4	7	10	
30	270	3.82^{h}	5.91^{fg}	8.59^{de}	6.11^{b}
	470	9.25^{de}	14.02^{b}	15.70^{ab}	13.00^{a}
	670	10.22^{cd}	14.89^{b}	17.29^{a}	14.14^{a}
40	270	5.17^{gh}	7.87^{ef}	11.28^{C}	8.10^{b}
	470	9.57^{cde}	15.02^{b}	17.13^{d}	13.91^{a}
	670	10.56^{cd}	15.09^{b}	17.35^{a}	14.39^{a}
Mean effect of weight		$C8.10^{C}$	12.14^{B}	14.59^{A}	
Mean of speed * weight					
270	4.49^{f}	6.89^{e}	9.93^{d}	Mean effect of speed	7.10^{B}
470	9.41^{d}	14.53^{c}	16.42^{ab}		13.45^{A}
670	10.39^{d}	14.99^{bc}	17.41^{a}		14.26^{A}
Mean of time * weight					
30	7.76^{d}	11.62^{bc}	13.86^{ab}	Mean effect of time	11.08^{B}
40	8.43^{dc}	12.66^{ab}	15.31^{a}		12.13^{A}
Least significance difference p<0.05					
Time: 0.683		Time* speed: 2.916		Time* speed* weight : 2.018	
Speed : 0.837		Speed* weight : 1.520			
Weight: 0.837		Time* weight : 3.425			

* The difference in the letters in each column indicate a significant differences between the averages of the treatments on a level of $p<0.05$.

$$\text{Unshelled grains} = \frac{\text{Weight of unshelled grains}}{\text{Weight of total grains}} \times 100 \quad (4)$$

Mechanically broken grains (%)

It was determined after a random sample of 200 gm was weighed out of each treatment. Afterwards, the broken seeds were isolated by suitable sieves according to the following formula given by Naveenkumar (2011):

$$\text{Broken grains} = \frac{\text{Weight of broken grains}}{\text{Weight of total grains}} \times 100 \quad (5)$$

RESULTS AND DISCUSSION

Shelling rate (kg/h)

Increasing the shelling time, as its illustrated from Table 2, from 30 sec to 40 sec led to an increase in the shelling rate from 11.08 to 12.13 kg/h. This is obvious because increasing time makes the amount of shelled seeds increased too due to the fact that more time is given to separate corn from cobs. This table also revealed that increasing the rotational speed of shelling from 270 to 420 then to 670 rpm caused a significant increase in the shelling rate from 7.10 to 13.45, then to 14.26 kg/h owing to the increase in the amount of separated seeds which are getting out of the threshing/ shelling sieve, synchronized with the increase of each speed, and this agrees with the results of Vinay (2016) and James *et al*. (2011). Additionally, this table depicts that the increasing in feeding with maize from 4 to 7 then 10 kg resulted in a significant increase in the shelling rate from 8.10 to 12.14 then 14.59 kg/h which is normal since the increase in the feeding rate with maize-kernels leads to an increase in the separated seeds from the kernels and this is in agreement with Udom (2013) and Naveenkumar (2011).

The effect of interaction between time and speed of shelling led to a significant increase in a higher threshing rate 14.39 kg/h at the time of 40 sec and speed of 670 rpm. The less threshing ratio 6.11 kg/h was obtained from time 30 sec and speed of 270 rpm. The interaction between shelling speed and machine feeding ratio showed a higher shelling ratio 17.41 kg/h with the

Table 3. Effect of time and speed of shelling and machine feeding rate on the consumed power (kW)

Threshing time (s)	Threshing speed (rpm)	Machine feeding rate (kg/h)			Effect of mean Time * speed
		4	7	10	
30	270	1.93^{e}	1.95^{e}	1.99^{e}	1.96^{b}
	470	1.92^{e}	2.00^{e}	2.09^{de}	2.00^{b}
	670	2.88^{ed}	2.54^{b}	2.84^{d}	2.55^{a}
40	270	1.93^{e}	1.96^{e}	1.98^{e}	1.95^{b}
	470	1.96^{e}	2.08^{de}	2.17^{d}	2.07^{b}
	670	2.49^{b}	2.45^{be}	2.93^{a}	2.62^{a}
Mean effect of weight		2.09^{B}	2.16^{B}	2.33^{A}	
Mean of speed * weight					
270	1.93^{d}	1.95^{de}	1.93^{d}	Mean effect of speed	1.96^{B}
470	1.94^{dc}	2.04^{dc}	1.94^{dc}		2.04^{B}
670	2.39^{b}	2.50^{b}	2.39^{b}		2.59^{A}
Mean of time * weight					
30	2.04^{a}	2.17^{a}	2.31^{a}	Mean effect of time	2.17^{A}
40	2.13^{a}	2.16^{a}	2.36^{a}		2.22^{A}
Least significance difference p<0.05					
Time: n.s		Time* speed: 0.197		Time* speed* weight : 0.232	
Speed : 0.119		Speed* weight : 0.189			
Weight: 0.119		Time* weight : n.s			

* Capital letters were written to indicate the single-factor effect, whereas small letters indicates for an interaction effect between the factors

speed of 670 rpm and weight 10 kg. While, the least shelling ratio 4.49 kg/h was obtained from the speed 270 rpm and weight 4 kg. The interaction between shelling time 40 sec and feeding weight 10 kg gave the highest shelling rate 15.31 kg/h, whilst the least threshing rate 7.76 kg/h, was with shelling time 30 sec, and feeding rate 4 kg. The interaction between the three parameters gave least significance effect, represented by a higher shelling rate 17.35 kg/h with time 40 sec and speed 670 rpm and weight 10 kg, while the least shelling rate 3.8 kg/h was with time 30 sec and speed 270 rpm and weight 4 kg.

Power consumed (kW)

Table 3 demonstrates the effect of time and speed of shelling and machine feeding rate, on the consumed power. It can be seen that the increasing of shelling time from 30 to 40 sec, didn't influence significantly on the consumed power. This is so obvious, whereby the time of threshing/shelling is not among the affecting factors on the consumed power while separating the corn seeds out of the cobs. Also, this table illustrates that increase in the shelling speed from 270 to 470 then to 670 rpm affected significantly by increasing the consumed power from 1.96 to 2.04 then to 2.59 kW, because increasing the engine load along with an increase in the speed of the rotating shaft, with which the chains are attached, demands more power out of the engine to rotate the shaft, and this is in agreement with Udom (2013) and James *et al*. (2011). Moreover, this table shows that the increase in the machine feeding rate from 4 to 7 then to 10 kg led to a significant increase in the consumed power from 2.09 kW to 2.16 kW then to 2.33 kW, this explains that each increase in the maize kernels weight that enters the threshing cylinder resulted in more power consumption by the rotating shaft to overcome this weight (Udom, 2013).

The interaction between time of shelling and speed led to a significant impact on the consumed power, whereby the highest consumed power was 2.62 kW at the time of shelling for 40 sec at the shelling speed of 270 rpm. While, the least consumed power ranged between 1.95-1.96 kW at the speed of 270 rpm and thresh-

Table 4. Effect of time and speed of shelling and machine feeding rate on the shelling efficiency (%)

Threshing time (s)	Threshing speed (rpm)	Machine feeding rate (kg/h) 4	7	10	Effect of mean Time * speed
30	270	79.54[cd]	74.49[ef]	71.34[ef]	75.12[c]
	470	100.00[a]	100.00[a]	100.00[a]	100.00[a]
	670	100.00[a]	100.00[a]	100.00[a]	100.00[a]
40	270	84.96[b]	81.09[c]	79.36[de]	80.80[b]
	470	100.00	100.00[a]	100.00[a]	100.00[a]
	670	100[a]	100.00[a]	100.00[a]	100.00[a]
Mean effect of weight		94.08[A]	92.59[AB]	91.28[B]	
Mean of speed * weight					
270	82.25[b]	77.79[c]	73.85[d]	Mean effect of speed	77.96[B]
470	100.00[a]	100.00[a]	100.00[a]		100.00[A]
670	100.00[a]	100.00[a]	100.00[a]		100.00[A]
Mean of time * weight					
30	93.18[a]	91.49[a]	90.44[a]	Mean effect of time	91.70[B]
40	94.88[a]	93.69[a]	92.12[a]		93.60[A]
Least significance difference p<0.05					
Time : 1.558	Time * speed : 2.607			Time* speed* weight : 3.592	
Speed : 1.908	Speed *weight : 2.985				
Weight: 1.908	Time*weight : n.s				

* n.s : No significant difference between treatments

ing time 40 sec - 30 sec, respectively. The interaction between threshing speed 670 rpm and feeding rate 10 kg resulted in the highest consumed power 2.88 kW, while the least consumed power was 1.93 kW with shelling speed 270 rpm and feeding rate 4 kg/h. The interaction between shelling time and weight of feeding rate showed a significant effect represented by the highest consumed power of 2.36 kW at the time 40 sec and weight of 10 kg, whereas the least consumed power was 2.04 kW at the time 30 sec and weight of 4 kg. The interaction between time and speed of shelling with feeding rate displayed a significant influence in the least consumed power ranged between 1.93-1.96 kW during both of the shelling time 30 and 40 sec with the speed of 270 and 470 rpm and weight of 4 kg. Whereas, the highest power consumption was 2.93 kW at the time 40 sec, speed of 670 rpm and weight of 10 kg.

Shelling efficiency (%)

Table 4 manifests the effect of time, speed of shelling and machine feeding rate on the shelling efficiency. It shows that the increasing time of shelling from 30 to 40 sec led to a significant increase in the shelling efficiency from 91.70 to 93.60 %. This is due to the increase in the shelling time accompanied with an increase in the grain amount at the expense of a decrease in the unshelled grains, so that the efficiency of shelling did increase. It's noted from this table that increasing speed of shelling from 270 to 470 then 670 rpm, influenced significantly on the shelling efficiency, and the speed of 270 rpm gave an efficiency of 77.96 %, while, the rest of speeds gave a shelling efficiency of 100%. This owing to the fact that the speeds of 470 and 670 rpm characterized in a complete shelling of grains clean cobs with no seeds attached to it, and that goes with (Udom, 2013; Al-Bannah, 1998; Vinay, 2016). Increasing the feeding rate from 4 to 7 the 10 kg caused a decrease in the shelling efficiency from 94.08 to 92.59 then 91.28% as a result of the increase in the unshelled grain that comes with the increase in feeding weight (Naveenkumar, 2011; Udom, 2013).

Time and speed of shelling interaction led to a significant influence of 100% shelling efficiency

Table 5. Effect of time, speed of shelling and machine feeding rate on the unshelled grains (%)

Threshing time (s)	Threshing speed (rpm)	Machine feeding rate (kg/h)			Effect of mean Time * speed
		4	7	10	
30	270	20.46^{cd}	25.51^{ab}	28.65^{a}	24.87^{a}
	470	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{c}
	670	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{c}
40	270	15.04^{e}	18.90^{d}	23.64^{bc}	19.19^{b}
	470	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{c}
	670	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{c}
Mean effect of weight		8.71^{A}	7.40^{AB}	5.91^{B}	
Mean of speed * weight					
270	17.75^{c}	22.20^{a}	26.14^{a}	Mean effect of speed	22.03^{A}
470	0.00^{d}	0.00^{d}	0.00^{d}		0.00^{B}
670	0.00^{d}	0.00^{d}	0.00^{d}		0.00^{B}
Mean of time * weight					
30	6.8^{a}	8.50^{a}	9.55^{a}	Mean effect of time	8.29^{A}
40	5.01^{a}	6.30^{a}	7.88^{a}		6.39^{B}
Least significance difference p<0.05					
Time : 1.558		Time * speed : 2.607		Time* speed* weight : 3.592	
Speed : 1.908		Speed *weight : 2.985			
Weight: 1.908		Time*weight : n.s			

*Similar letters in each column indicate that there are no significant differences between the averages of the treatments on a level of p<0.05

through the speeds 470 and 670 rpm at the time of 30 and 40 sec. The speed of 270 rpm resulted in a decrease in the shelling efficiency from 80.80 to 75.12% at the time 40 and 30 sec, respectively. The interaction between rotational speeds and feeding rates showed a significant effect on the shelling efficiency reached 100% at the speeds 470 and 670 rpm along with all the feeding rates, while the efficiency decreased at the speed of 770 rpm and reached 73.85% along with a feeding rate of 10 kg/h. The interaction of time with feeding rate led to a significant influence of 94.98% at the speed of 40 sec and feeding rate of 4 kg/h. The least efficiency 90.44% was recorded at the time 30 sec and weight of 10 kg/h. The interaction between time, speed of shelling and feeding rate clarified a significant impact of the highest efficiency 100% with time of shelling and speeds of 470 and 670 rpm. Whilst, the least shelling efficiency was 71.34% with time 30 sec, speed of 270 rpm and weight of 10 kg.

Unshelled grains (%)

It is noticed from Table 5 that increasing the time of threshing from 30 to 40 sec accompanied a significant decrease of unshelled grains from 8.29 to 6.39%, this is so obvious, whereby increasing the time led to better separating for the rest of the grains remained attached to the cobs, that made the ratio of unshelled grains lesser (Azeez *et al*., 2017). This table also shows that the shelling speed 270 rpm had unshelled grains ratio of 22.03%, while the shelling speed of 470 and 670 rpm didn't have any unshelled grains, due to the fact that the speed of 470 rpm was very suitable in relation with the shelling cylinder diameter and the amount of maize entering the cylinder (James *et al*., 2011; Abagissa and Befikadu, 2015). Increasing feeding rate from 4 to 7 then to 10 kg led to an increasing in the unshelled grains from 5.91 to 7.40 then 8.71% since increasing weights of the machine feeding rate caused an imperfect contact between the threshing chains and the corns. Both Naveenkumar (2011) and Udom (2013) emphasized on the necessity of adjustment of machine feeding rates. The interaction between time and speed of shelling had a significant impact upon less unshelled

Table 6. Effect of time, speed of shelling and machine feeding rate on the broken grains (%)

Threshing time (s)	Threshing speed (rpm)	Machine feeding rate (kg/h)			Effect of mean Time * speed
		4	7	10	
30	270	0.00^{g}	0.00^{g}	0.00^{g}	0.00^{b}
	470	0.00^{g}	0.00^{g}	0.00^{g}	0.00^{b}
	670	18.36^{b}	9.75^{e}	9.25^{f}	12.45^{a}
40	270	0.00^{g}	0.00^{g}	0.00^{g}	0.00^{b}
	470	0.00^{g}	0.00^{g}	0.00^{g}	0.00^{b}
	670	19.75^{a}	11.5^{c}	10.16^{d}	13.80^{a}
Mean effect of weight		6.35^{B}	3.54^{B}	3.23^{B}	
Mean of speed * weight					
270	0.00^{d}	0.00^{d}	0.00^{d}	Mean effect of speed	0.00^{B}
470	0.00^{d}	0.00^{d}	0.00^{d}		0.00^{B}
670	19.05^{a}	10.62^{b}	9.70^{c}		13.13^{A}
Mean of time * weight					
30	6.12^{a}	3.25^{a}	3.08^{a}	Mean effect of time	4.15^{A}
40	6.58^{a}	3.83^{a}	3.38^{a}		4.60^{A}
Least significance difference $p<0.05$					
Time : n.s	Time * speed : 2.489		Time* speed* weight : 0.397		
Speed : 1.468	Speed *weight : 0.788				
Weight: 1.468	Time*weight : n.s				

*The mean values at the end of the table refer to the LSD values of the study factors and their interaction grains 19.19% at the time of 40 sec and speed of 270 rpm, whereas the speeds of 470 and 760 rpm didn't produce unshelled grains at both times. The interaction between speed of shelling and feeding rate significantly influenced the unshelled grains ratio, recorded the highest ratio 26.14% with speed 270 rpm and weight 10 kg, whereas the speeds of 470 and 670 rpm didn't record any unshelled grains with all the weights. The interaction between time of shelling and feeding rate had no significant effect on the unshelled grains. The interaction between time, speed of shelling and feeding rate had a significant effect on the ratio of unshelled grains, while the speed 470 and 670 rpm significantly recorded better results in the least unshelled grains ratio with all the treatment. The unshelled grains were confined to the rotational speed of 270 rpm, where it wasn't the best alternative for shelling.

Broken grains (%)

Table 6 illustrates that increasing the time of shelling from 30 to 40 sec had no significant impact on the ratio of broken grains. It's noted that the speed of shelling influenced significantly on the ratio of broken grains, speed of 670 rpm gave broken grains 13.13%, however the speed of 270, 470 rpm didn't accompany any broken grains. This is owing to the fact that the higher rotational speed exceeded the appropriate limit that didn't suit the volume of the sheller and shelling mechanism (James *et al*., 2011; Sobowale *et al*., 2015). This table also depicts that increasing the feeding weight from 4 to 7 then to 10 kg led to a decrease in the broken grains ratio from 19.75 to 11.5 then to 10.16%. That is due to increasing the weight entering the machine which acts as a cushion that reduces the effect of the grains with the threshing chains, this results in reducing the ratio of the broken grains (AL-Bannah, 1998; Mahmoud and Buchele, 1975).

The interaction between time and speed of shelling led to non-broken grains at both time and speeds of shelling of 270 and 470 rpm, however the speed of 670 rpm had an increasing in the broken grains from 12.45 to 13.80% along with increasing time from 30 to 40 sec. The interaction between speed of shelling and machine feeding weights had a significant impact on the non-broken grains at the speeds of 270 and 470 rpm along with all feeding weights. However, grains did break with the speed of 670; the highest ratio was 19.05% with a weight of 4 kg. The interaction between time of shelling and feeding weights didn't have a significant influence on the broken grains. However, the triple interaction of the parameters had a significant effect on the non-broken grains at the speeds of 270 and 470 rpm at both times of shelling along with all feeding rates; however grains did brake at the speed of 670 rpm with a ratio of 19.75% at the time 40 sec and weight 4 kg.

CONCLUSION

- The time of shelling effected significantly on the ratio and efficiency of shelling as well as unshelled grains, while it had less impact on the consumed power and broken grains.
- The variation of the rotational speed of shelling and the weights of feeding influenced significantly on the shelling ratio, consumed power, shelling efficiency, unshelled seeds, and broken grains.
- The combination of the shelling time 30 sec, speed of 470 rpm, and weight of 10 kg gave the best measured parameters, which can be adopted later as standards for shelling purpose.

REFERENCES

Abagissa H and Befikadu D. 2015. Modification and testing of jimma adjustable hand maize sheller. *Journal of Multidisciplinary Engineering Science and Technology*, 2(6): 1375-1377.

Al-Bannah AR. 1998. Harvesting equipment, ministry of higher education and scientific research. Al Mosul University, Iraq. 424 p.

Adewole CA, Babajide TM, Oke AM, Babajide NA, Aremu DO and Ogunlade CA. 2015. Critical evaluation of locally fabricated maize shelling machine. *International Journal of Engineering Science and Innovative Technology,* 4(2): 67-73.

Al-Desouky N, Mousa E and Lotfy A. 2007. Feasibility of using corn seller machine in threshing sunflower. *Journal of Agriculture and Environmental Science Alexandria University,* 6(3): 17-33.

Azeez TM, Uchegbu ID, Babalola SA and Odediran OO. 2017. Performance evaluation of a developed maize sheller. *Journal of Advancement in Engineering and Technology,* 5(2): 1-4.

Bako T and Boman JB. 2017. Design, fabrication and performance evaluation of a hand operated maize sheller. *Journal of American Science,* 13(8): 68-76.

James KM, Umogbai V and Itodo I. 2011. Development and evaluation of a melon shelling and cleaning machine. *Journal of Emerging Trends in Engineering and Applied Sciences,* 2(3): 383-388.

llori TA, Raji AO and Kilanko O. 2013. Modelling some ergonomic parameters with machine parameter using hand powered maize sheller. *Journal of Engineering and Technology Research,* 5(3): 52-57.

Mahmoud AR and Buchele WF. 1975. Distribution of shelled corn throughput and mechanical damage in a combine cylinder. *Transactions of the ASAE,* 18(3): 444-452.

Mali PK, Sakhale CN and Rapelli DO. 2016. Assessment of maize thresher for rural dwellers by human powered flywheel motor concept. *International Journal of New Technologies in Science and Engineering,* 3(1): 36-41.

Naveenkumar DB. 2011. Modification and evaluation of power operated maize (*Zea mays* L.) sheller. Thesis, University of Agricultural Sciences, Bangalore. 107 p.

Payne JD. 1997. Trouble shooting: The pelleting process-Part 1 and 2. Borregaard Ligno Tech, UK. 1-10 p.

Patil K, Shamuvuel P, Gajendra P, Sunil K and Jadhav AJ. (2016). Design and fabrication of corn shelling and threshing machine. *International Journal for Innovative Research in Science and Technology*, 5 (7): 13981-13986.

SAS. 2004. SAS/STAT/ User's guide for personal computers, release 6.12, *SAS Institute Inc.*, Cary, NC, USA.

Sobowale SS, Adebiyi JA and Adebo OA. 2015. Design, construction and performance evaluation of a melon seeds sheller. *Journal of Food Process Technology,* 6(7): 1-5.

Udom SC. 2013. Operating factors of Thai threshers affecting corn shelling losses. *Journal of Science and Technology,* 35(1): 63-67.

Vinay. 2016. Design and development of pedal operated maize sheller. College of Agricultural Engineering and Technology, CCS Haryana Agricultural University, Thesis, 62 p.