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Modified and Evaluating the Chinese Shelling Maize Machine

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ABSTRACT

Mechanical shelling maize is an important operation in all over the worldwide to decrease the number of labors, time and reduce cost. The Chinese machine was modified and operated by an electric motor which was evaluated at different shelling drum speeds of 1000, 1400, 2000 and 2800 rpm (4.45, 6.23, 8.9 and 12.46 m/sec), four different rear cone clearance of 25, 30, 35 and 40 mm and four different tilt angles of drum 3, 7, 12 and 16˚ at constant moisture content (MC) of 13 % and constant front cone clearance of 70 mm. The results showed that at an optimum drum speed of 2000 rpm, the productivity of maize sheller was 497 kg/h, grain damage of 0.28 % shelling efficiency of 99.25 %, Specific energy requirement of 3.38 kW h/t and operating cost of 37.97 EGP/t at the constant MC of 13 %, constant front cone clearance of 70 mm, rear cone clearance of 35 mm and recommended tilt angle of 12˚. The study provided information and baseline knowledge for improving the shelling maize to obtain high shelling efficiency, save cost, time and labors during shelling maize.

Keywords: Shelling maize; Machine; Drum; Electric motor; Productivity; Shelling efficiency.

INTRODUCTION

Shelling of maize (*Zea mays* L.) in general is carried out by using three different methods: manual, semi-mechanical and mechanical. Up to now most of shelling maize in Egypt is essentially carried out manually in the small farms. Manual shelling of maize is conducted by removal of the grains with one's fingers. It is a too slow process average productivity about 2.7 kg/h and requires much time and labor, but it cases minimum losses and grains damage compared with mechanical shelling. In Egypt, most of the farmers shelling maize by mainly three methods namely shelling ear grain by hand; hand-operated maize sheller and beating by stick technique were carried for removing maize grain from the ear. The maize shelling was designed and built to enhance the standards of people living in villages of developing countries. There are many electrical operated maize shelling machines for shelling maize. In 2017, Egypt maize planting area about 920601 hectares and production nearly 7.1 million tons (FAO, 2017).

Aremu *et al.* (2015), stated that shelling efficiency and output capacities were 87.08 and 623.99 kg/h, respectively which were at highest values at 13 % MC of maize and at 886 rpm shelling speed. It is easier for shelling the maize grains at MC between 13% and 14% (w.b.) (Adegbulugbe, 1986 and Adewale *et al.* 2000). The efficiency of shelling decreased with an increase in MC and the highest efficiency of shelling about 95.6 % was obtained at 13% MC (Alonge and Adegbulugbe, 2000). Vindizhev and Blaev (1983), indicated that the clearance at the concave end should be less than that at the concave front. Metwalli *et al.* (1995 b), compared between two maize shelling drums, triangle rasp-bar and triangle spike-tooth. Five drum speeds, four clearance ratios and five kernel moisture contents were tested to estimate grain damage and unshelled grain. Triangle rasp-bar drum is strongly recommended for its good performance. The grain damage and unshelled grains were 3.86 % and 1.95 %, respectively, at 10.26 m/s drum speed, 1.8 to 2.1 (inlet clearance/outlet clearance) for 18 to 20 % moisture contents as a condition of the triangle rasp-bar drum. Choe *et al.* (1985), found that the highest shelling performance was obtained at the drum speed 600 rpm, 15.5-16.0 % of corn MC. Under these conditions, the prototype has a capacity of 2591 kg/h in corn shelling and 2.5 % of kernel damage. Nalbant (1990), found that the damaged grain percentage raised with raise in MC and drum speed. Metwalli *et al.* (1995 a), manufactured a small suitable corn shelling machine from local materials to suit the demands of Egyptian farmers. A comparison test performance of the manufactured machine compared with another small French shelling machine. The test performance includes unshelled grain, grain damage and economical operating cost. The performance of the machines was influenced by both drum speed and concave clearance ratio at different moisture contents during shelling corn ears. The manufactured machine was developed to be suitable as possible for different grain crops with a minimum adjustment by using a rasp-bar cylinder. The manufactured machine was found to be better in shelling efficiency and grain damage.

Mady (2016), stated that by increasing drum speed lead to increase each of damaged kernels, losses kernels and machine productivity. On the other side, increasing drum speed from 23.02 to 41.9 m/sec tends to decrease the undamaged kernels and machine efficiency. The least value of damaged kernels (1.5%) and the highest values of undamaged kernels (98.5 %) were obtained at the MC of 13.3 %.

Abd EL Maksoud (1996), studied some factors affecting the performance of newly established small corn sheller at different three MC of kernels and four corn varieties. He found that the optimum shelling efficiency was 97.5 % at kernels MC 18 % (w.b.) and speed 280 - 320 rpm for all varieties. The minimum total losses (6 - 10 %) was obtained when speed ranged from (280 to 600 rpm) and the same kernel MC for most corn varieties. Abdel Wahab *et al.* (2011), developed, evaluated the performance of a corn shelling machine, indicted that the optimum concave clearance and drum speed for shelling two corn varieties was 42 mm, and 670 rpm (8.77 m/s), respectively. Mady (2004), found that the suitable level of kernel MC during shelling was 15.5 % with drum speed of 450 rpm and 50 mm clearance of concave which reduced the broken kernels up to 6.5 % and increased the unbroken kernels up to 93.5 %.

Zaalouk (2013), developed a small corn sheller for a rural dweller which operated by using an electric motor. The results revealed that productivity, kernels damage percentage and power consumption with all sizes of corn ears increased with the increase of operating speed. The

heights shelling efficiency and sheller productivity of (99.65, 99.61, and 99.48%) and (94.38, 127.02 and 138 kg/h) at operating speeds 229, 275 and 330 rpm, respectively with all sizes of corn ear. It is recommended that the operating of the corn sheller was 275 rpm to achieve average shelling efficiency of 99.35 %, unshelled kernels of 0.65 %, damage kernels of 5.25 % and productivity of 98.8 kg/h. El Sharawy *et al.* (2017), stated that productivity of sheller, the efficiency of shelling, and the percentage of the unshelled grains ranged from 0.43 to 1.46 t/h, from 94.25 to 99.43 %, and from 0.57 to 5.75 %, respectively.

The objectives of the present study are to modified a maize sheller suitable for Egyptian farmer and evaluate its performance under different operational parameters.

MATERIALS AND METHODS

Experiments were carried out at El Ibrahimia, Governorate of Al Sharkia, Egypt in the summer season of 2018. This study aimed essentially modified and evaluated the Chinese shelling maize machine.

Materials

The maize variety (TWC 321) at a constant MC of 13 % and the mean of some characteristics of maize ear are provided in Table 1. From previous references, the MC in this study was constant at 13%.

Table 1. Mean values of some characteristics of maize ear (TWC 321).

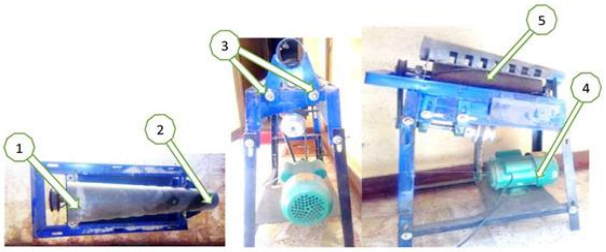
Maize characteristic	Average value
Maize ear length, mm	200
Maize ear diameter, mm	45
Maize ear mass, g	185
Number of grains on one cob	517
Maize grains mass on one cob, g	150
Maize cob diameter, mm	33
Maize cob mass, g	35

Machine specification after modified:

The modified machine in this study was used for shelling maize. It was consisting of mainframe, shelling unit, machine cover and transmission system Figs. (1& 2).

(a) Mainframe:

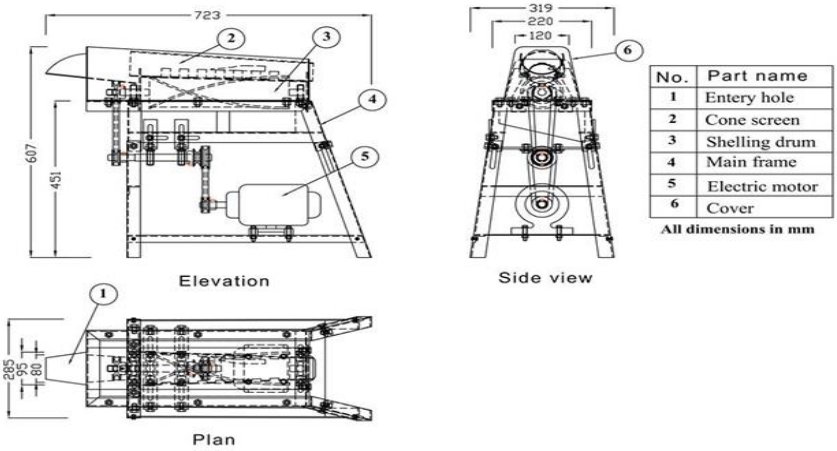
The mainframe of a machine which carries shelling unit, machine cover and electric motor. It constructed of iron angle with dimensions of (30×30×2 mm). Dimensions of the mainframe with a length of 633 mm, a width of 319 mm and a height of 451 mm.



No.	Part name	No.	Part name
1	Front of cone concave	4	Electric motor
2	Rear of cone concave	5	Shelling drum
3	Control bolts of rear clearance		

Picture of modified machine with cover.

Fig. 1. Pictures of the modified machine for shelling maize.



No.	Part name
1	Entery hole
2	Cone screen
3	Shelling drum
4	Main frame
5	Electric motor
6	Cover

All dimensions in mm

Fig. 2. The modified machine for shelling maize.

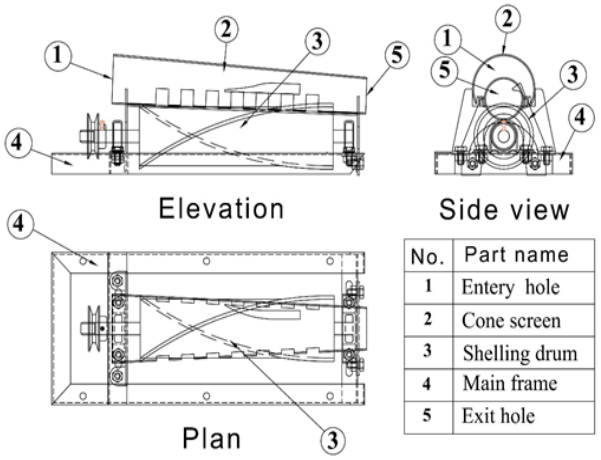
(b) Shelling unit:

The shelling unit was consisting of shelling drum and cone screen (Fig. 3). The shelling drum was constructed of cylinder iron sheet metal with a thickness of 3 mm. The shelling drum was 310 mm in length and 85 mm in diameter. Fixed on shelling drum two-cylinder bars with dimensions of 5 mm in diameter and 325 mm in

length. Shelling drum fixed by two bearings on the mainframe.

There are two screws bolts in the rear of cone screen lifting free movement up and down to adjust the rear clearance cone on different sizes. There are eight screws bolts on all sides of the top part of the machine, two for each side, fixed on the front, right side, rear and left side of the machine free movement up and down to adjust the tilt angle of drum and cone. Constant front cone clearance of 70 mm and four different rear cone clearance of 25, 30, 35 and 40 mm.

Picture of the modified machine (shelling drum and cone) without cover.



No.	Part name
1	Entery hole
2	Cone screen
3	Shelling drum
4	Main frame
5	Exit hole

Fig. 3. The shelling drum and cone.

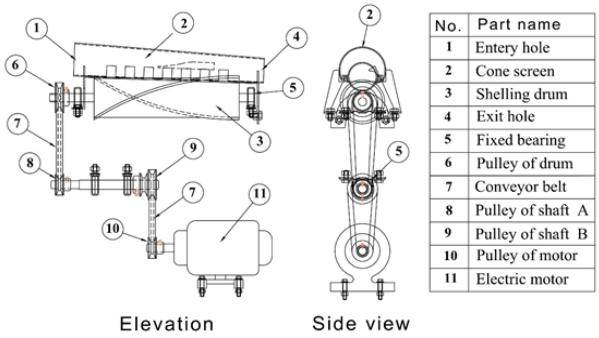
Cone screen made on conical shape with iron sheet metal 3 mm in thickness. Dimensions of cone screen were 406 mm in length, height of the entry hole 83 mm and height of the exit hole 57 mm.

(c) Machine cover:

Constructed from a sheet of iron metal with a thickness of 1.5 mm. The cover was 156 mm in height, 495 mm in length and 220 mm in width.

(d) Transmission system:

The motor power of 2.4 kW and 2800 rpm maximum rotating speed is transmitted motion to shelling drum using pulleys and V-belts. Fixed the first pulley on the motor shaft with the diameter of 50 mm, fixed the second pulley on conveyor shaft with two diameters of 70, 100 mm and the next side of conveyor shaft fixed to another pulley with a diameter of 50 mm to transmitted motion to shelling drum using V-belt. The shelling drum pulley with a diameter of 70 mm to get different speeds for the drum speed is shown in (Fig. 4).



No.	Part name
1	Entery hole
2	Cone screen
3	Shelling drum
4	Exit hole
5	Fixed bearing
6	Pulley of drum
7	Conveyor belt
8	Pulley of shaft A
9	Pulley of shaft B
10	Pulley of motor
11	Electric motor

Fig. 4. Transmission system.

Machine before modified:

The original machine is operated at constant drum speed of 2800 rpm, constant front cone clearance of 70 mm, rear cone clearance of 40 mm, constant tilt angle for drum and cone of 14˚ and constant maize MC of 13 %.

The average productivity of the machine is 405 kg/h, average grain damage of 1%, average unshelled grains of 4 %, average shelling efficiency of 96 % and average specific energy of 5.68 kW h/t.

Methods:

Experimental conditions:

The modified shelling machine was evaluated under the following parameters:

- **Four shelling drum speeds:** 1000, 1400, 2000 and 2800 rpm (4.45, 6.23, 8.9 and 12.46 m/sec),
- **Four rear cone clearance:** 25, 30, 35 and 40 mm,
- **Four rear tilt angles of drum and cone:** 3, 7, 12 and 16˚.

Measurements:

The developed machine was evaluated by using the following devices and equations:

Electrical balance:

OHAUS model was made in U.S.A used for measuring the weight of maize grains, ears and cobs. The maximum mass measuring by the electrical balance was 2610 g with 0.1 g accuracy.

Tachometer:

The laser tachometer measuring the rotating speed of the shelling drum, and the electric motors shaft. This tachometer measure rotating speeds up to 19999 rpm with ± 0.05 % accuracy.

Stopwatch:

Each treatment measured the consumed time by the digital stopwatch Casio with accuracy 1/100 second to record the time.

Digital vernier

A vernier calliper was used to measure the dimensions of ears and cobs with an accuracy of 0.05 mm.

Clamp meter and voltmeter:

Measuring current intensity and voltage, respectively. The device was made in Japan; Type: Super clamp meter 700k 600v~Ac.50 Hz; Measurements: Ac. Amperage, Voltage and Resistance.

Machine productivity:

The productivity of the modified shelling machine was calculated as follows:

$$S_p = M_1 / T \quad (1)$$

Where:

S_p = The productivity of the modified shelling machine, kg/h.

M_1 = The mass of shelled grains, kg; T = The consumed time, h.

Unshelled grains:

After shelling operations, the unshelled grains were shelled manually from the ears and weighted then unshelled grains percentage were calculated as follows:

$$UN_g = M_2 / (M_1 + M_2) \times 100 \quad (2)$$

Where:

UN_g = The unshelled grain on cobs, %; M_1 = The mass of shelled grains, kg;
M_2 = The mass of unshelled grains, kg.

Shelling efficiency:

Shelling efficiency was calculated as determined by El Sharawy *et al.* (2017):

$$SE = (1- UN_g) \times 100 \quad (3)$$

Where:

SE = The shelling efficiency of the modified machine, %.

Grain damage:

The grain damage percentage was calculated as follows:

$$G_d = M_d / M_t \times 100 \quad (4)$$

Where:

G_d = The grain damage, %; M_d = The mass of damaged grains, g;
M_t = The mass of total grains sample, g (100 g).

Power consumed:

Estimating the power required was determined by Ibrahim (1982):

$$P = V \times I \times \cos\theta \times \frac{1}{1000} \quad (5)$$

Where:

P = The power required, kW; I = The intensity of current, Ampere;
V = Voltage, Volt; cos θ = Factor of power, 0.84;
θ = The phase angle between current and voltage.

Specific energy requirements:

The requirements of specific energy for the modified shelling machine was calculated as follows:

$$SER = P / S_p \times 1000 \quad (6)$$

Where:

SER = The specific energy requirements, kW h/t.

Operating cost:

The hourly cost of the modified shelling machine was determined by El Awady *et al.*, (2003):

$$C = p/h (1/a + i/2 + t + r) + (W.e) + m/144 \quad (7)$$

Where:

C = The cost for working during one hour, EGP/h; P = The price of the machine, EGP; h = Working hours during one year, h/y; a = The life expectancy of the machine, y; i = Rate of interest for one year, %; t = Ratio of taxes overheads, %; r = Repairs and maintenance ratio, %: W = The consumed power, kW; e = Price of the kilowatt per hour, EGP/kW h; m = Monthly salary for an operator, EGP; 144 = The average number of working hours during a month; h.

$$\text{Operating cost} = (C / S_p) \times 1000 \text{ , EGP/t} \quad (8)$$

RESULTS AND DISCUSSION

The obtained results will discuss the following items:

Productivity

Shelling drum speed is the principal parameter governing the productivity of the modified shelling machine. Figure 5 shows that, at the constant MC of 13 %, front cone clearance of 70 mm and tilt angle of 12˚ by increasing the shelling drum speed from 1000 to 2800 rpm, productivity increased from 249 to 617, from 254 to 646, from 260 to 664 and from 251 to 631 kg/h at rear cone clearance of 25, 30, 35 and 40 mm, respectively.

These results agree with Naveenkumar and Rajshekarappa (2012), who reported that the productivity of sheller was found significantly different for each sheller arrangement and speed combination at moisture contents. The higher productivity of sheller (402.01 kg/h) was found when maize MC 13 % fed to sheller having drum speed of 350 rpm.

The shelling drum speed influences the productivity of the shelling machine as well feed as rate. It is noticed that the highest productivity of the shelling machine at rear cone clearance of 35 mm, front cone clearance of 70 mm, tilt angle of 12˚ and at the constant MC of 13 % for all drum speeds.

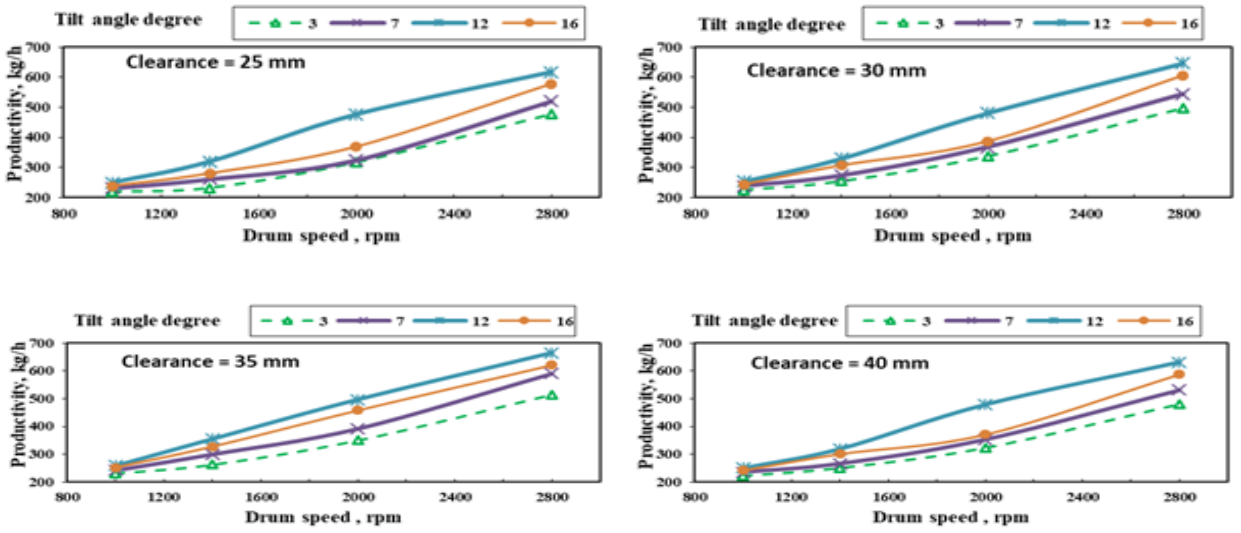


Fig. 5. Effect of different drum speeds, different rear cone clearances and different tilt angles on productivity for modified shelling machine.

Grain damage

The results show that the shelling drum speed is the principal parameter governing the grain damage of the modified shelling machine. Figure 6 shows that, at MC of 13 %, constant front clearance of 70 mm and tilt angle of 12˚ by increasing the shelling drum speed from 1000 to

2800 rpm, grain damage increased from 0.27 to 0.44, from 0.23 to 0.39, from 0.15 to 0.37 and from 0.13 to 0.28 % at rear cone clearance of 25, 30, 35 and 40 mm, respectively. Minimum grain damage of 0.02 % found at 1000 rpm drum speed, 16˚ tilt angle, 70 mm front cone clearance, 40 mm rear cone clearance and MC of 13 %.

These results agree with El Sharawy *et al.* (2017), who stated that the percentage of grain damage at kernel outlet ranged from 0.21 to 2.13 %.

The grain damage decreased with increased tilt angle and cone clearance at all drum speeds this could be attributed to moving ear very fast and did not hit by drum enough and cone clearance wider to moving ear faster.

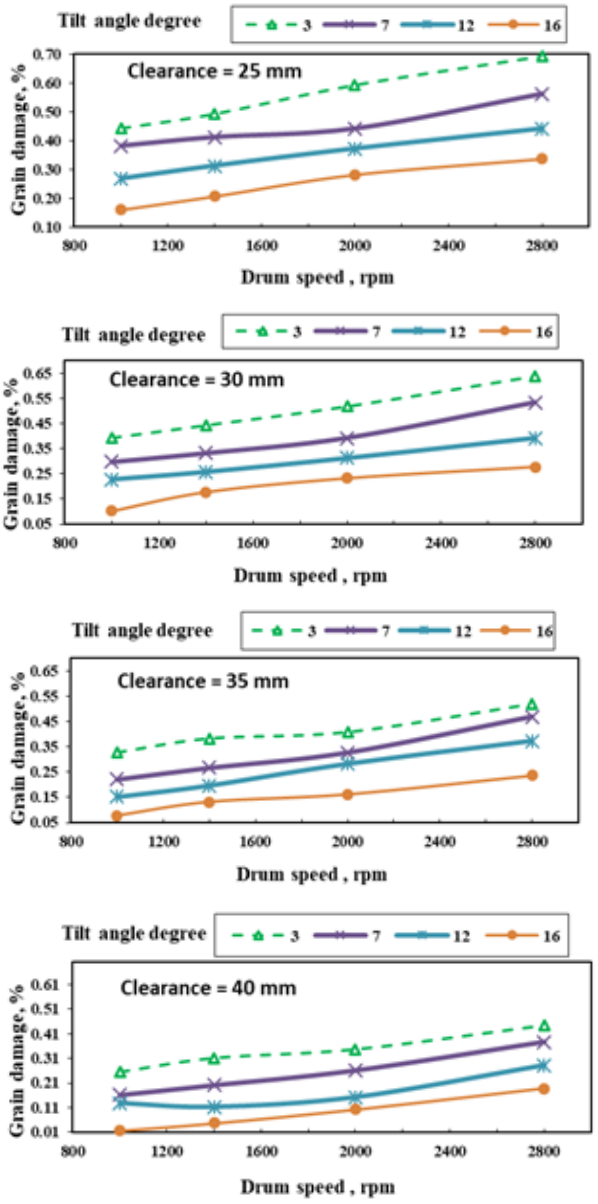


Fig. 6. Effect of different drum speeds, different rear cone clearances and different tilt angles on grain damage percentage for modified shelling machine.

Shelling efficiency

The results for the modified shelling machine indicated that, at MC of 13%, constant front cone clearance of 70 mm and tilt angle of 12˚ by increasing the shelling drum speed from 1000 to 2800 rpm, shelling efficiency increased from 92.66 to 96.61, from 95.59 to 98.91, from 96.34 to 99.90 and from 95.30 to 97.98 % at rear cone clearance of 25, 30, 35 and 40 mm, respectively (Fig. 7).

This result could be attributed to the large influence of shelling drum speed on increasing shelling efficiency by reduced un shelling grains remain on cobs, so modified shelling machine facilitates the shelling operation.

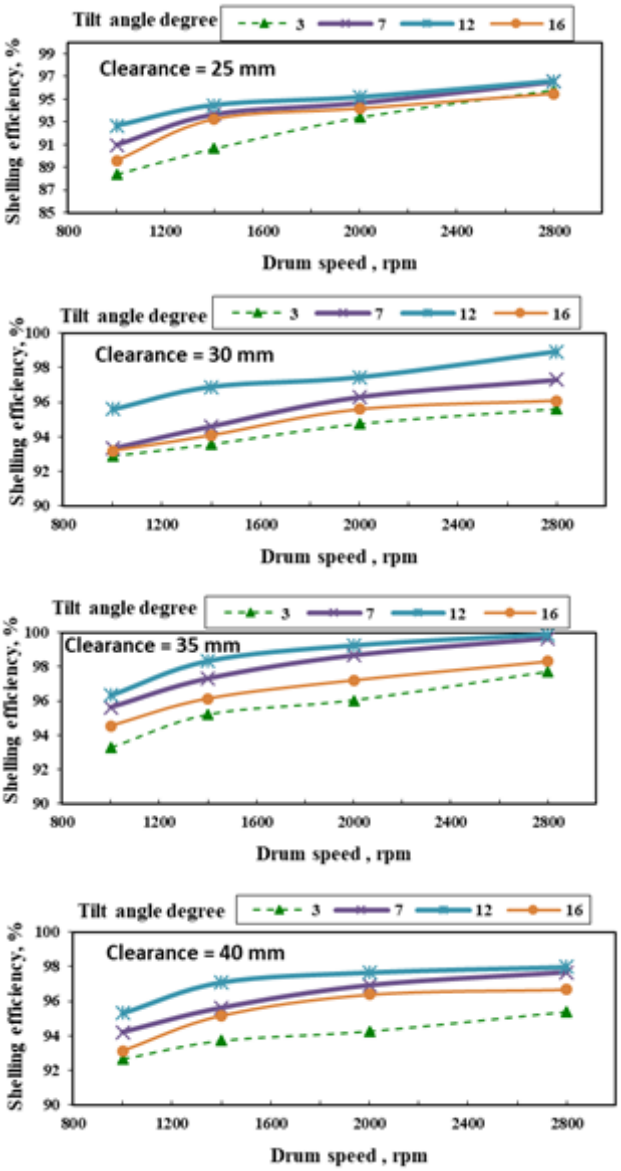


Fig. 7. Effect of different drum speeds, different rear cone clearances and different tilt angles on shelling efficiency for modified shelling machine.

Specific energy requirement

The results for the modified shelling machine indicated that, at MC of 13%, constant front cone clearance of 70 mm and tilt angle of 12˚ by increasing the shelling drum speed from 1000 to 2800 rpm, the requirement of specific energy decreased from 7.23 to 3.40, from 6.77 to 3.05, from 6.19 to 2.86 and from 5.82 to 2.87 kW h/t at rear cone clearance of 25, 30, 35 and 40 mm, respectively (Fig. 8).

These results coincide with El Sharawy *et al.* (2017), who reported that specific energy consumption decreased with increased rotational speed.

These results could be attributed to productivity greater in proportion than the power consumed with increased drum speed.

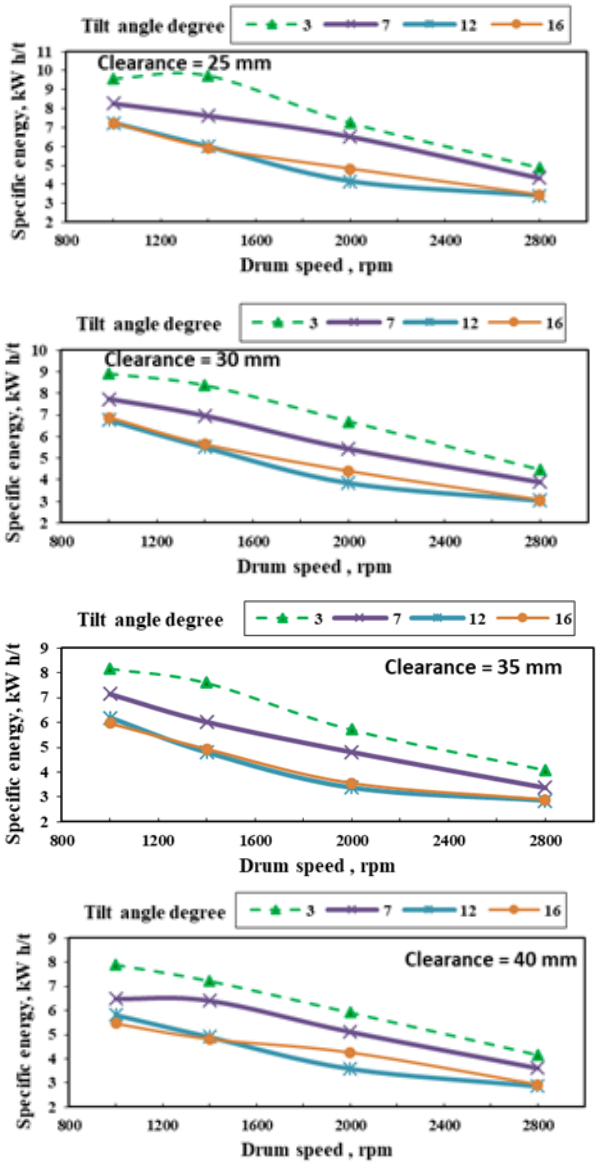


Fig. 8. Effect of different drum speeds, different rear cone clearances and different tilt angles on the specific energy requirements for modified shelling machine.

Operating cost

Relating the use of modified shelling machine, the obtained results in Fig 9 indicated that at MC of 13%, constant front cone clearance of 70 mm and at tilt angle of 12˚ indicated that, by increasing shelling drum speed from 1000 to 2800 rpm, operating cost decreased from 76.22 to 31.20, from 74.44 to 29.62, from 72.34 to 28.72 and from 74.40 to 30.09 EGP/t at rear cone clearance of 25, 30, 35 and 40 mm, respectively.

These results coincide with El Sharawy *et al.* (2017), who indicated that operating cost decreased by increasing rotational speed and operating cost ranged from 18.19 to 64.42 EGP/t.

This was due to the high influence of shelling drum speed increased productivity for one hour more than increased the cost of working for one hour.

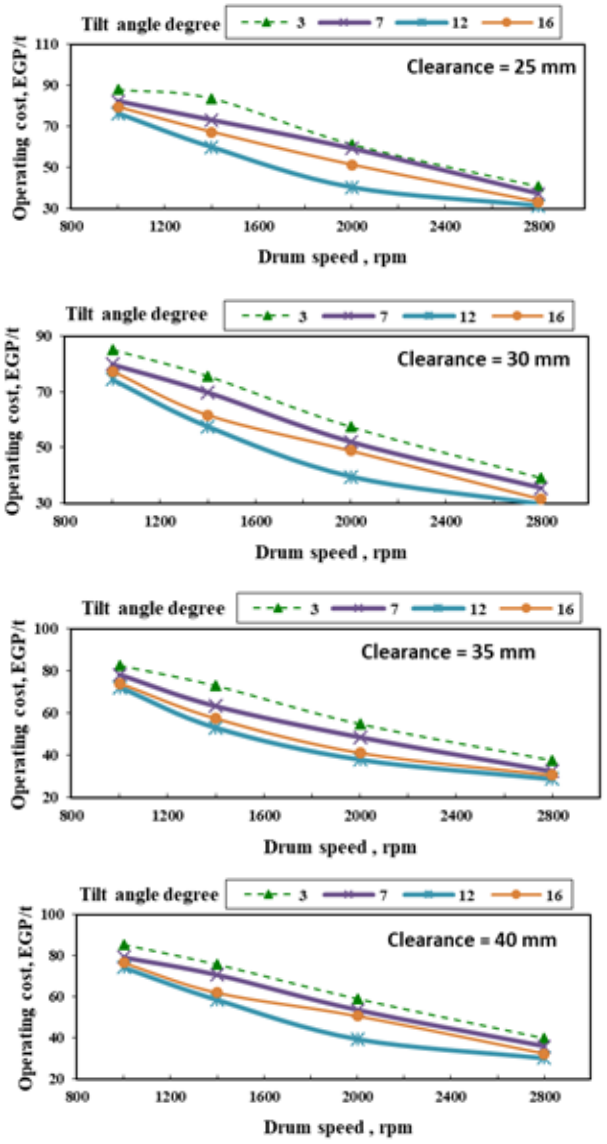


Fig. 9. Effect of different drum speeds, different rear cone clearances and different tilt angles on operating cost for modified shelling machine.

CONCLUSION

Conclusion of this study can be summarized as follows, the machine of shelling maize was modified and tests showed that at the optimum drum speed of 2000 rpm the productivity of modified shelling machine about 497 kg/h, grain damage of 0.28 %, shelling efficiency of 99.25 %, specific energy requirement of 3.38 kW h/t and operating cost of 37.97 EGP/t at the constant MC of 13 %, constant front cone clearance of 70 mm, rear cone clearance of 35 mm and tilt angle of 12˚.

Minimum grain damage of 0.02 % was obtained at 1000 rpm drum speed, 16˚ tilt angle, 70 mm front cone clearance, 40 mm rear cone clearance and 13% MC. The

study provided information and baseline knowledge for improving the shelling maize to obtain high shelling efficiency, save cost, time and labors during shelling maize.

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تعديل وتقييم أداء آلة تفريط الذرة الصينية

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عملية تفريط الذرة من العمليات الهامة ما بعد الحصاد وهي تجرى يدويا في مصر في المزارع الصغيرة وعند صغار المزارعين والتفريط اليدوي عملية بطيئة جدا ويتم إضاعة الكثير من الوقت والعمالة والمال والمجهود. تم تعديل آلة تفريط الذرة الصينية الصنع والتي تعمل بمحرك كهربائي ٢.٤ كيلو وات على سرعة واحدة وخلوص أمامي واحد وخلوص خلفي واحد وزاوية ميل درفيل واحدة ثم اجري تقييم الآلة بعد التعديل تحت المتغيرات التالية: أربع سرعات مختلفة لدرفيل التفريط ١٠٠٠ و١٤٠٠ و٢٠٠٠ و٢٨٠٠ لفة على الدقيقة (٤,٤٥ و٦,٢٣ و٨,٩ و ١٢,٤٦ م\ث) وأربع خلوصات بين طرف الدرفيل والصدر النصفي العلوى الذى يمر فيه كوز الذرة من نهاية الأسطوانة الخلفية ٢٥ و ٣٠ و٣٥ و٤٠ مم وخلوص أمامي ثابت ٧٠ مم و أربع زوايا ميل للدرفيل ٣ و ٧ و ١٢ و ١٦ درجة. وجد أن سرعة الدرفيل ٢٠٠٠ لفة\دقيقة هي المثلى لآلة التفريط حيث كانت الإنتاجية ٤٩٧ كجم\ساعة ونسبة تكسير للحبوب ٠.٢٨ % وكفاءة التفريط تصل إلى ٩٩.٢٥ ٪، الطاقة النوعية المستهلكة ٣.٣٨ كيلو وات. ساعة\ طن وتكاليف تشغيل ٣٧.٩٧ جنيه\طن عند محتوى رطوبة ثابتة ١٣ ٪ الموصي بها في الأبحاث السابقة وزاوية ميل ١٢ درجة وخلوص أمامي ٧٠ مم وخلوص خلفي ٣٥ مم. أقل نسبة تكسير للحبوب ٠.٠٢ % عند سرعة ١٠٠٠ لفة\دقيقة للدرفيل وزاوية ميل ١٦ درجة وخلوص أمامي ٧٠ مم وخلوص خلفي ٤٠ مم ونسبة رطوبة ثابتة ١٣ %. قدمت الدراسة المعرفة والمعلومات الأساسية لتحسين تفريط الذرة للحصول على كفاءة عالية في التفريط ، وتوفير الوقت والتكلفة وعدد العمال. الآلة الصينية تحت الدراسة أعطت أقل نسبة تكسير للحبوب سواء قبل التعديل أو بعد التعديل مقارنة بآلات التفريط الأخرى وذلك لاعتمادها في عملية التفريط على احتكاك البروزين الممتدين على درفيل التفريط ومع الجزء السفلى للكوز أثناء حركتها العلوية من مدخل مجرى الكوز إلى خروجه من الجهة الأخرى وهذه العملية تشبه التفريط اليدوي وبعكس الآلات الأخرى التي تعتمد على اصطدام الكيزان والحبوب بمضارب الدرفيل التي تؤدى إلى نسبة كسر كبيرة لحبوب الذرة في تلك الآلات.