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DEVELOPMENT AND EVALUATION OF A POWER OPERATED CORN SHELLER.

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ABSTRACT

A power–operate corn sheller was constructed to investigate the effect of corn moisture content, concave clearance and cylinder rotating speed on the broken and whole corn kernels percentages, total losses percentage as well as shelling efficiency and sheller productivity (kg/h) .The experiments were conducted at four levels of kernels moisture content of 12 , 15.5 , 19.2 and 23 %, three concave clearances of 30 , 40 and 50 mm and four cylinder rotation speeds of 450,500,550 and 600 rpm, (9.4 , 10.5, 11.5 and 12.6 m / s). The results indicated that decreasing the cylinder speed and increasing the concave clearance tends to reduce the percentage of kernel broken and shelling efficiency and increase the percentage of kernel whole and total losses at all kernels moisture contents. The minimum percent of kernel broken of 6.5% and the highest kernel whole of 93.5% were found at concave clearance of 50 mm, cylinder rotating speed of 450 rpm (9.4 m/s) and kernels moisture content of 15.5%. However, the least percent of kernel losses of 4.6% and the highest percent of shelling efficiency of 95.4% were recorded at concave clearance of 30 mm, cylinder rotating speed of 600 rpm (12.6 m/s) and kernels moisture content of 12%.

The results also revealed that the highest machine productivity of 215.5 kg/h was obtained at concave clearance of 30 mm, cylinder rotating speed of 600 rpm (12.6 m/s) and kernels moisture content of 12 %.

INTRODUCTION

Corn is considered one of the most important cereal crops in Egypt. The total planted area is 2078258 feddans and the total production reaches up to 6842316 t. with an average yield of 3.29 t. /fed. (Agric. Exetn. Iss., 2001).In Egypt, most of the corn planted area is harvested manually. Corn shelling is an important process after harvesting compared with other operations in manual harvesting. Hand shelling of corn is very slow process and requires much time and labor, but it causes minimum losses and seed damage compared with mechanical shelling.So, this study objective to develop and construct a prototype of small corn sheller to shell satisfactorily most of corn varieties and also to suit the small farms.

Mahmoud and Buchele (1975) found that ear axis parallel to cylinder axis orientation suffered the least damage at all moisture content levels tested, followed by ears fed randomly to the cylinder. The highest damage was suffered by ears fed with their axis perpendicular to the cylinder .The minimum damage for all orientations was at 20 to 22% moisture content. They found that the corn kernel damage increased with an increase in moisture content and cylinder velocity.

Chowdhury and Buchele (1976) found that kernel moisture content and cylinder speed were highly significant in analysis of variance for damaged corn kernel percentages. Chowdhury and Buchele (1978) reported that total damage increased from 26% to 41% as cylinder velocity increased from 450 to 650 rpm(12.8 and 18.7 m/s). Minimum total damage was sustained at 23% moisture content (w.b). They found that the mechanical damage by the laboratory sheller ranged between 26.3 and 42% for cylinder velocities.

Hamid *et al.* (1980) stated that, a laboratory corn sheller was designed, constructed, and tested to evaluate its ability to shell corn with little kernel damage . The sheller consisted of three inclined rollers rotating in the same direction but at different speeds. The ears were fed axially between the rollers through a guide. The experimental sheller did not produce any measurable corn fines and caused only slight damage to the shelled kernel. The unbroken cobs resulting from shelling the ears were an indication of a gentle shelling process. Damage and breakage tendency comparisons at 18 percent kernel moisture content showed that the experimental sheller behaved more like hand- shelling than like a combine cylinder. The corn shelled by the experimental sheller had significantly less damage than the corn shelled by the combine cylinder and its breakage tendency after handling was significantly lower than that of combine – shelled corn or that of sound kernels stored from samples shelled by the combine cylinder. The low damage inflicted to kernels during shelling by the experimental sheller suggests that this shelling method merits consideration for commercial application.

Nalbant (1990) studied the percentage of corn grain damage caused by the cylinder and concave before and after the grains were shelled from the cob. The effect of grain moisture content and cylinder velocity on grain damage was also investigated. Cylinder velocity of 7 and 11 m/s were used in the shellers. Corn varieties were shelled with grain moisture content of 15, 20 and 15 %. Damaged grain percentage increased with an increase in moisture content and cylinder velocity. Mechanical damage was also affected by the concave clearance, physical and morphological properties of corn ear and feeding rate. Cold test germination percentage of sound grains showed no effect by the cylinder type and velocities.

Tastra *et al.* (1992) tested three types of local corn shellers at three levels of grain moisture content and cylinder speed. The effective shelling capacity increased with an increase in cylinder speed but decreased with an increase in the corn moisture content. Therefore, shelling cost increases with an increase in moisture content. Mechanically damaged corn increased with increasing of cylinder speed and corn moisture content.

Liao *et al.* (1994) stated that, machine vision systems have been developed for detection of corn kernel breakage and have shown promising results. Most machine vision systems are designed to classify corn kernels into two or more damage categories, such as no damage, minor damage, and severe damage. One problem with this approach is that mechanical damage occurs on a continuous scale from hairline cracks and tiny spots of pericarp missing to complete breakage, which makes separation of damaged kernels difficult. It would be useful to have machine vision systems that determine the damage level on a continuous scale that is proportional to the damage severity.

Ajav and Igbeka (1995) tested the performance of corn sheller using an international standard code to study the general qualities and design of sheller. The results show that the shelling efficiency of the sheller varies with moisture content, speed of the shelling unit and feed rate. The machine has a shelling efficiency of 98 %, 95 % and 94 % when shelling corn with a moisture content of 11, 20 and 25 %, respectively. The sheller has a cleaning efficiency of 93, 87 and 85 % when shelling corn with moisture content of 11, 20 and 25 % respectively, with a shelling unit speed of 400 rpm and fan unit speed of 750 rpm. The sheller has a capacity of 260 kg/h. The performance tests proved that the sheller performs best at shelling unit speed of 450 rpm with minimum losses and high efficiency.

Kumar and Parvathi (1998) studied the energy expenditure of woman laborers for corn shelling using tubular, modified tubular and hand operated corn shellers. The energy expenditure was compared with the traditional method of shelling. Three female subjects with similar anthropometric parameters were selected to operate the corn sheller. It was estimated that the average energy expenditure for operating of the different manual shellers was 5-6 k cal / min. The output of the hand operated corn sheller was 23 kg/h , 92% higher than the hand operated, modified tubular and tubular corn sheller saved energy expenditure by 80, 60 and 52 %, respectively, compared to the traditional method. The energy requirement to work these shellers without fatigue was 2200 k cal / day.

Ng *et al.* (1998) stated that machine vision algorithms were developed for measuring corn kernel mechanical damage and mold damage. Mechanical damage was determined using both single – kernel and batch analysis by extracting from kernel images the damage area stained by green dye and by calculating the percentage of total projected kernel surface area that was stained green. Mold damage was determined using single – kernel analysis by isolating the moldy area on kernel images and by calculating the percentage of total projected kernel surface area covered by mold. The vision system demonstrated high accuracy and consistency for both mechanical and mold damage measurements. The standard deviation for machine vision system measurements was less then 5 % of the mean value, which is substantially smaller than for other damage measurement methods.

MATETIALS AND METHODS

The Giza 9 variety at different levels of moisture content was used to test and evaluate the locally fabricated corn sheller.

Corn Sheller

The new mechanical sheller was constructed at the Agric. Mech. Brach, Soil and Water Dept., Faculty of Agric., Suez Canal Univ. The sheller consists of an iron cylinder length of 660 mm and 260 mm diameter assembled on an axial shaft of 30 mm diameter rested on two bearings fixed on the frame. The cylinder circumference is divided into three zones. The first zone facing the feeding opening fixed on the circumference rubbery fingers. The second zone `fixed on the circumference iron fingers and the third zone facing the expel opening fixed on the circumference hammers to expel the cobs outside on the rear of corn sheller. All fingers fixed on the cylinder circumference. The sheller concave made of galvanized iron sheet of 1mm thickness pierced to hole of 14mm diameter and fitted under the cylinder. The cylinder rotates at different speeds through transmission pulleys and belts powered by an electric motor as shown in Fig. (1)and Fig. (1-A). The developed sheller was preliminarily tested to study some parameters affecting shelling operation as follows:

1- Four cylinder rotating speeds of 450, 500, 550, and 600 rpm (9.4, 10.5, 11.5 and 12.6 m/s.).
2- Three concave clearances of 30, 40, and 50 mm.
4- Four levels of kernel moisture content of 12, 15.5, 19.2, and 23 %.

The effect were studied of the above mentioned parameters on the broken and whole corn kernel percentage, unshelled (losses) kernel percentage , shelling efficiency and machine productivity. The feed rate was kept constant at the best performance level according to the results of the preliminary tests.

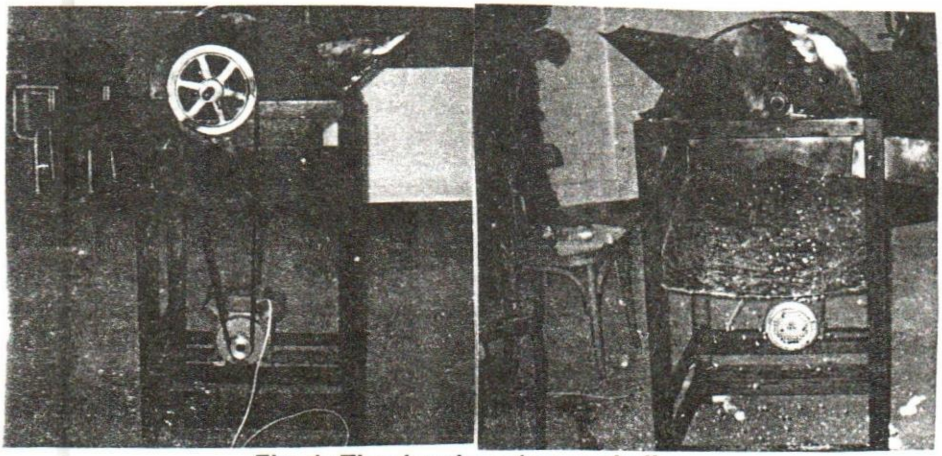

Fig. 1: The developed corn sheller.

Broken and whole corn kernels:

Three random samples of corn kernels were taken during shelling operation. Each sample weighed (W)kg and was divided into two portions, broken corn kernels (Bk) and whole kernels (Wk). The average weight of broken corn kernel (m1) and whole kernels (m2) were recorded and the percentage of the each portion was calculated as follows :

$$Bk = (m1 / W) * 100 \quad \%$$

$$Wk = (m2 / W)* 100 \quad \%$$

Shelling losses:

Three random samples of corn ears were fed into the sheller . After completed shelling operation the unshelled (losses) kernel from the ears were shelled manually and weighed (m) kg. The shelling losses percentage (Lk) was calculated as follows:

$$Lk = (m / W) * 100 \quad \%$$

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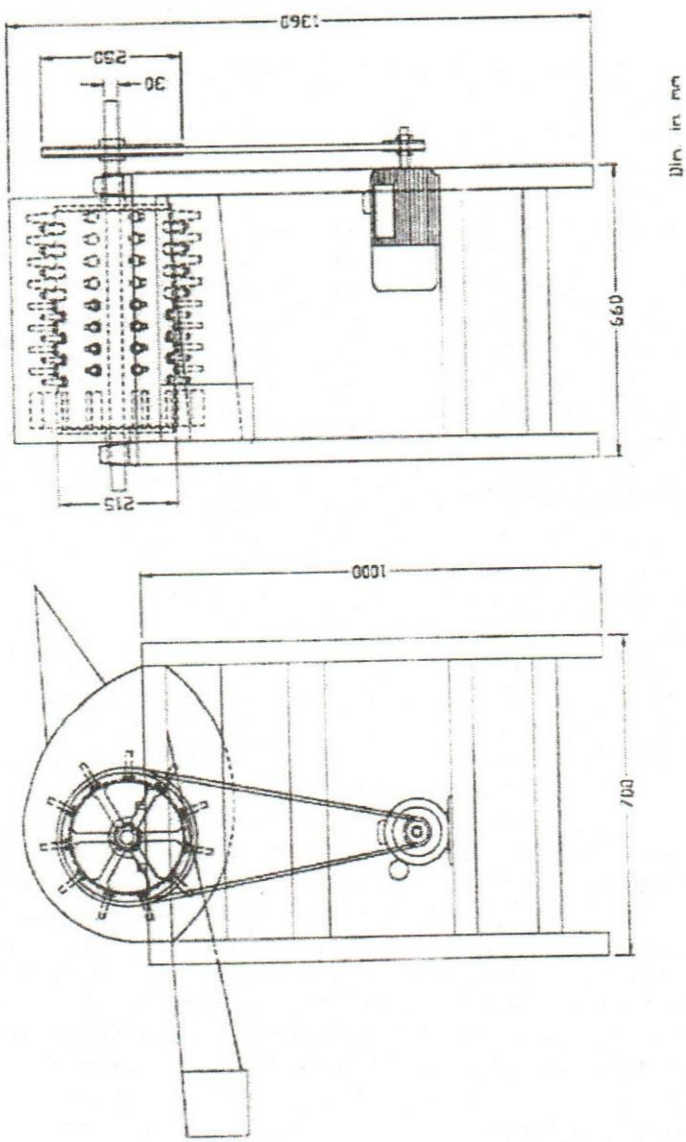

Fig. (1-A):Developed corn sheller

Shelling efficiency :

Shelling efficiency of corn sheller (E) was estimated as follows:

E = [1 – Lk] %

Machine Productivity:

Four samples each of 10 kg of corn ears were fed into the machine and the shelling time (T) in minutes was recorded. The machine productivity (Mp) kg/h was calculated as follows:

Mp = (W * 60) / T

RESULTS AND DICUSSION

Effect of kernels moisture content :

Data in Table (1) show that the kernel moisture content had positive affects on broken and losses kernels and negative effects on whole kernel, shelling efficiency and machine productivity. The least12.8m/s and 18.7 m/s kernel broken of 10.56 % was obtained at kernels moisture content of 15.5 %.It was increased with each increase in moisture content over this limit (15.5 %). Also, reducing the moisture content to be 12 % resulted in marked increase in the broken kernels percentage compared with the moisture content of 15.5 %. On the other hand , each increase in moisture content tends to increase the losses (unshelled kernels)and decrease the whole kernels percentage and shelling efficiency and machine productivity. The minimum losses of 8 % and the highest shelling efficiency of 92 % and machine productivity of 201.87 kg/h were obtained at kernels moisture content of 12 %. Meanwhile, the highest losses of 12.83 % and lowest shelling efficiency of 87.15 % and machine productivity of 187.25 kg/h were recorded at kernels moisture content of 23 %.

Effect of concave clearance:

The results in Table (1) reveal that the concave clearance had positive effect on whole kernels and losses kernels and negative effects on broken kernels and shelling efficiency and machine productivity. The lowest broken kernels of 11.96 % and the highest whole kernels of 88.04 % were obtained at concave clearance 50mm. On the other hand, the minimum kernels losses of 7.6 % and the highest shelling efficiency of 92.4 and machine productivity of 199.43 kg/h were recorded at concave clearance 30 mm. So, it can be stated that the concave clearance adjustment depends upon the purpose of corn kernels production. In case of kernels production for seeding, the concave clearance should be increased to be 50 mm for minimizing the broken kernels and hence increasing the whole kernels percentage. However, the concave clearance should not be increased more than 30 mm for general consumption of corn kernels.

Effect of cylinder rotary speed:

From Table (1), it can be stated that the cylinder speed also had positive effect on broken kernels, shelling efficiency and machine productivity and negative effect on whole and kernel losses. The minimum broken kernels of 13.89 %, shelling efficiency of 88.34 % and machine productivity of 187.26kg/h and the highest whole kernels of 86.11 % and kernel losses of 11.66 % were obtained at cylinder speed of 450 rpm (9.4 m/s). Meanwhile, the highest broken kernels of 18.36 %, shelling efficiency of 91.29 % and the lowest whole kernels of 81.54 % and kernel losses of 8.71 % were recorded at cylinder rotary speed of 600 rpm (12.6 m/s). From the obtained results, it can be reported that, the cylinder speed must be limited according the purpose of corn kernels production. For seeding production of the corn kernels, the cylinder speed should not be more than 450 rpm (9.4 m/s) for raising the whole kernels percentage. However for local consumption of corn kernels in human food and animal feeding, the cylinder speed should be increased to 600 rpm (12.6 m/s).

The statistical analysis of the results reveal that the relation contribution for kernels moisture content, concave clearance and cylinder rotating speed was 0.841. The kernels moisture content had the highest relation contribution (R^2 = 0.496) followed by the concave clearance (R^2 = 0.269), while the cylinder speed comes last (R^2= 0.076). Most limiting factor in broken kernels and kernel losses percentage was kernels moisture content. The same trend was found with the whole kernels percentage and shelling efficiency and machine productivity where kernels moisture content was the highest followed by concave clearance and lastly cylinder speed.

Table 1: Broken, whole and losses kernel percentage as well as shelling efficiency and machine productivity of corn as affected by each of concave clearance, cylinder speed and kernels moisture content.

Treatments	Kernels broken, %	Kernels whole, %	Kernels losses, %	Shelling efficiency, %	Machine productivity, (kg/h)
Concave clearance					
30mm	20.21 a	79.79 c	7.60 c	92.40 a	199.43 c
40mm	15.51 b	84.49 b	9.92 b	90.07 b	194.61 e
50mm	11.96 c	88.04 a	13.12 a	86.88 c	190.13 g
Cylinder rotary speed					
450 rpm	13.89 d	86.11 a	11.66 a	88.34 d	187.26 h
500 rpm	14,65 c	85.35 b	10.72 b	89.27 c	192.15 f
550 rpm	16.69 b	83.32 c	9.76 c	90.24 b	197.03 d
600 rpm	18.36 a	81.64 d	8.72 d	91.29 a	202.40 a
Kernels moisture content					
12.0 %	12.43 c	87.58 b	8.00 d	92.00 a	201.87 b
15.5 %	10.56 d	89.44 a	9.12 c	90.88 b	197.31 d
19.2 %	16.70 b	83.30 c	10.90 b	89.10 c	192.46 f
23.0 %	23.90 a	76.10 d	12.83 a	87.15 d	187.25 h

Means followed by the same letter are not significantly different at 5% level of probability

Interaction effects :

Figs. (2 and 3) show the effect of concave clearance and cylinder speed on the broken, whole and kernel losses percentage as well as shelling efficiency and machine productivity. The results reveal that the least broken kernels of 10.5 % and the highest whole kernels of 89.5 % were found at concave clearance of 50 mm and cylinder speed of 450 rpm (9.4 m/s). Meanwhile, the highest broken kernels of 22.91 % and the lowest whole kernels of 77.09 % were recorded at concave clearance 30 mm and cylinder speed of 600 rpm (12.6 m/s). On the other hand, the minimum kernel losses of 6 % and the highest shelling efficiency of 94 % were obtained at concave clearance of 50 mm and cylinder speed of 600 rpm. However, the highest losses kernels of 14.32 % and lowest shelling efficiency of 85.68 % and machine productivity of 183 kg/h were found at concave clearance of 50mm and cylinder speed of 450 rpm. So, the suitable concave clearance and cylinder speed for seeding production were 50 mm and 450 rpm, respectively. However, for local consumption of corn, the suitable treatment was 30 mm for concave clearance and cylinder speed of 600 rpm.

Figs. (4 and 5) reveal the effect of concave clearance and kernels moisture content on the broken, whole and kernel losses percentage as well as shelling efficiency and machine productivity. The results indicated that the broken kernels percentage reached its minimum value of 7.96 % and the highest whole kernels of 92.04 % were obtained when the concave clearance was 50 mm and kernels moisture content was 15.5 %. However, the least kernel losses (5.88 %) and high shelling efficiency of 94.12 % and machine productivity of 206.48 kg/h were found at concave clearance of 30mm and kernels moisture content of 12 %.

Figs. (6 and 7) show the effect of interaction between cylinder speed and kernels moisture content on the broken, whole, and kernel losses percentage as well as shelling efficiency and machine productivity. The lowest broken kernels of 8.57% and the highest whole kernels of 91.43 were found at cylinder speed of 600 rpm with moisture content of 15.5 % which gave the minimum kernel losses of 6.77 % and the highest shelling efficiency of 93.27% and machine productivity of 209.93 kg/h .

Finally, the minimum percent of broken kernels of 6.5 % and the highest whole kernels of 93.5% were found at concave clearance of 50mm and cylinder speed of 450 rpm (9.4 m/s) and kernels moisture content of 15.5 %. However, the least percentage of kernel losses (4.6%) and the highest percent of shelling efficiency of 95.4% and machine productivity of 215.5 kg/h were recorded at concave clearance of 30mm, cylinder speed of 600 rpm and moisture content of 12 %. The statistical analyses of multiple linear regression and stepwise regression technique show that, the broken, whole and kernel losses percentage as well as shelling efficiency can be expressed with the following equations:

Broken kernels; % = -3.32 – 0.41cc + 0.03 Cs + 1.11 m.c
Whole kernels; % = 103.3 + 0.41 Cc – 0.03 Cs + 1.11 m.c
Losses kernels; % = 1.68 + 0.28 Cc – 0.02 Cs + 0.44 m.c
Shelling efficiency; = 98.32 – 0.27 Cc + 0.02 Cs + 0.44 m.c

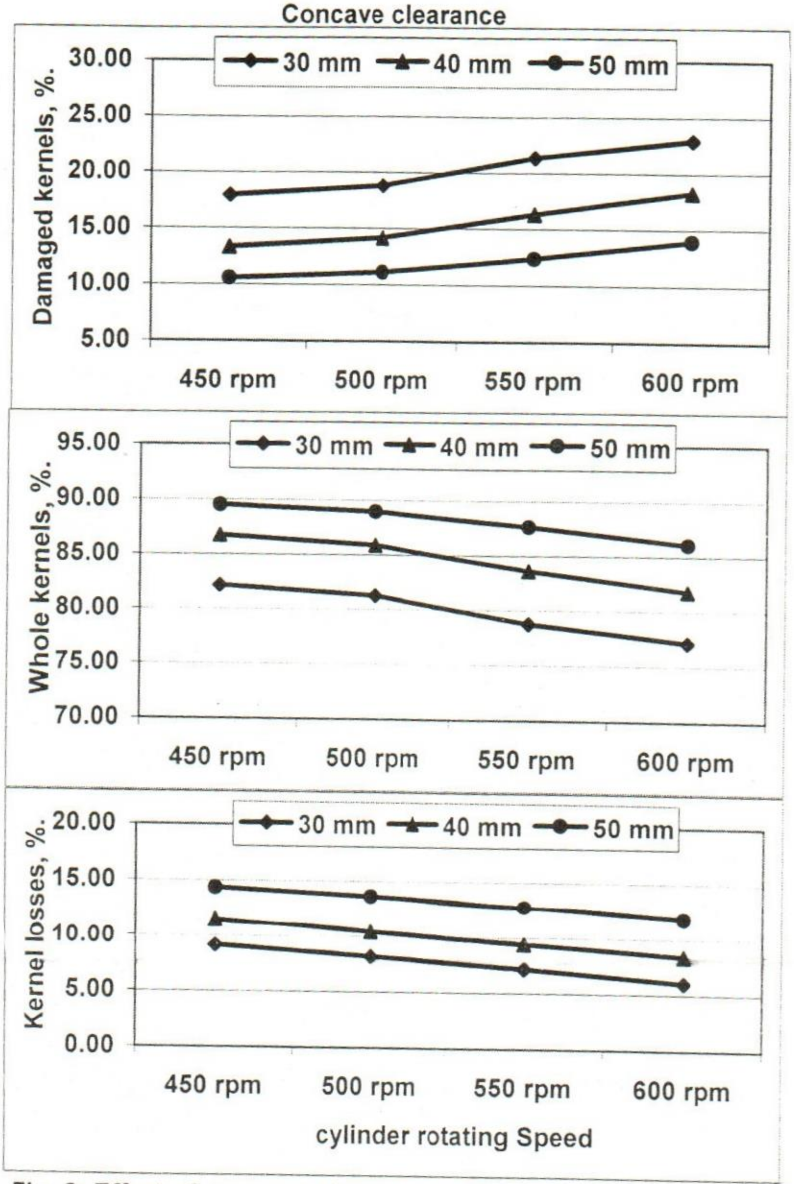

Fig. 2: Effect of concave clearence and cylinder rotating speed on the broken, wholeand losses kernels, and shelling effeciency

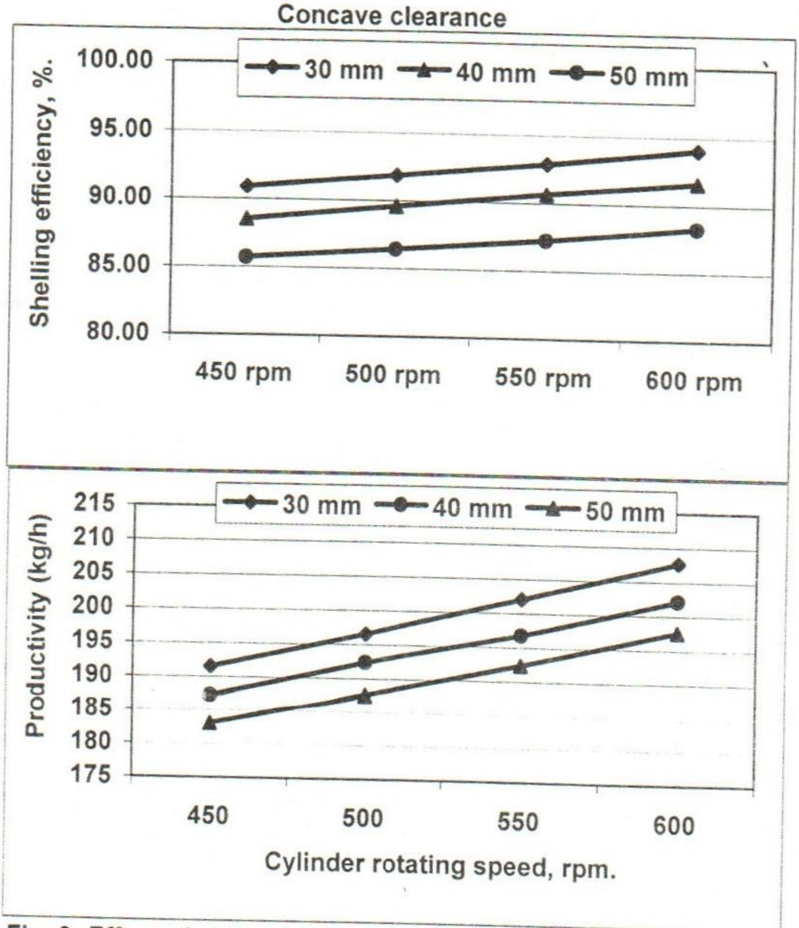

Fig. 3: Effect of concave clearence and cylinder rotating speed on shelling effeciency and machine productivity

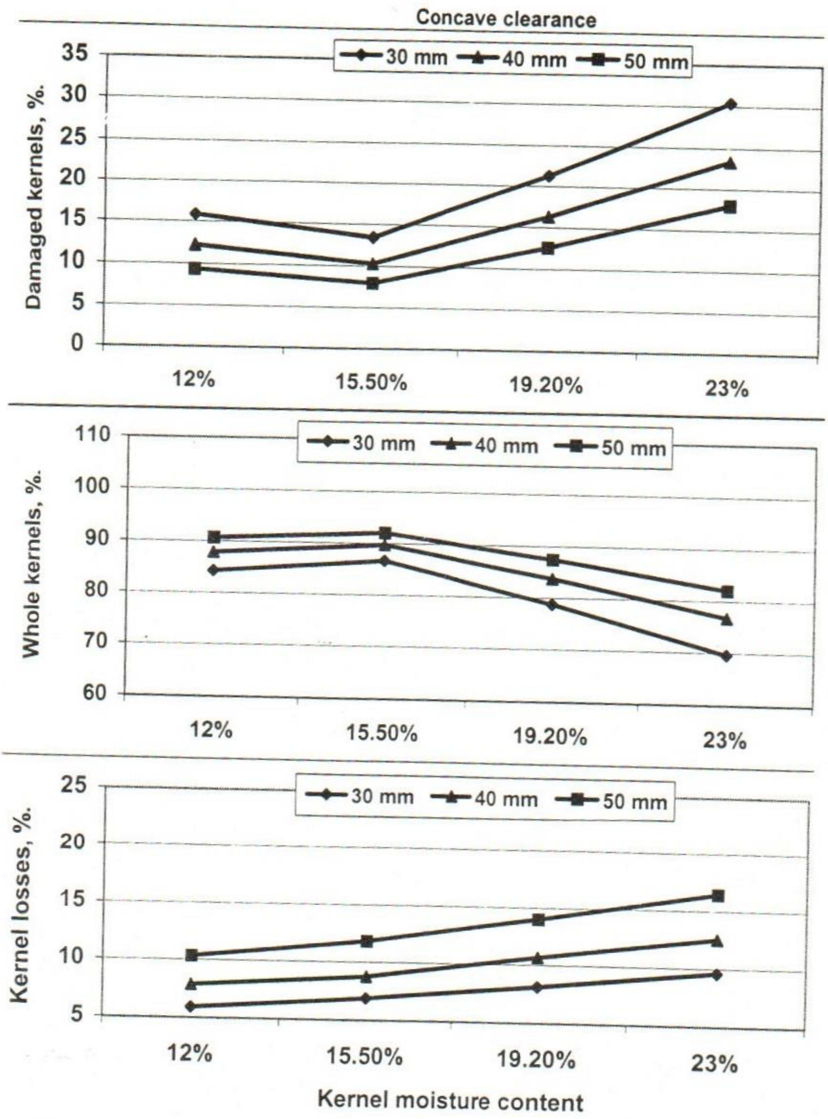

Fig. 4: Effect of concave clearence and kernel moisture content on the broken kernels,whole kernels,losses kernels and shelling effeciency.

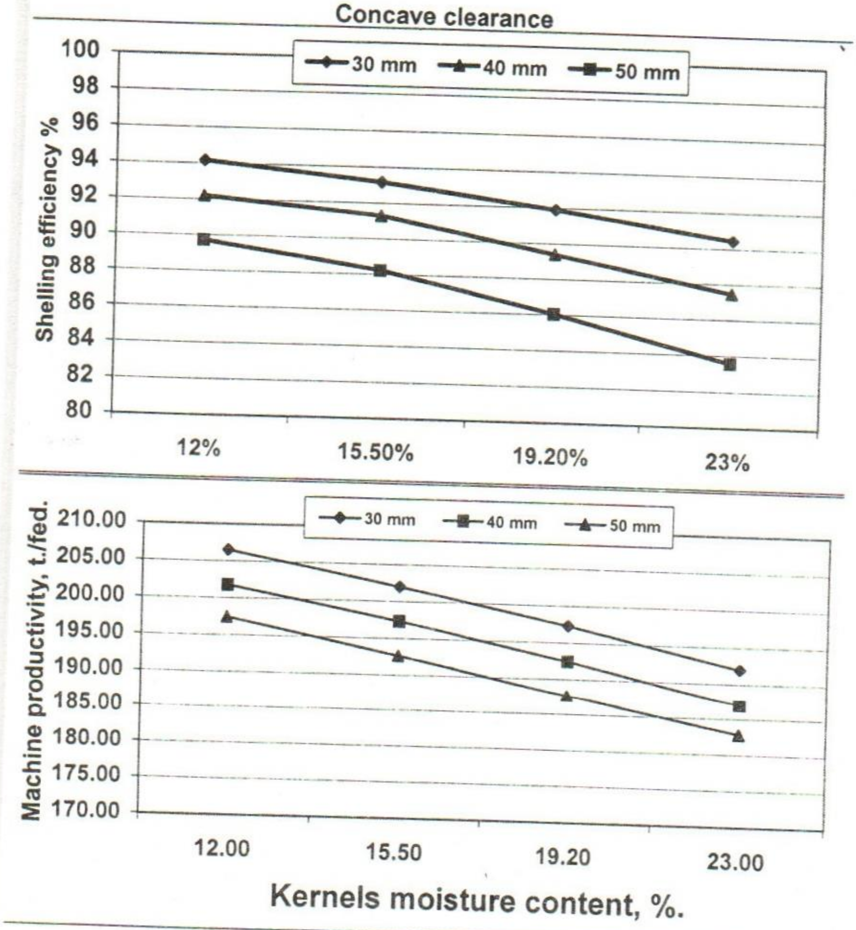

Fig. (5): Effect of concave clearence and kernels moisture content on the shelling effeciency and machine productivity.

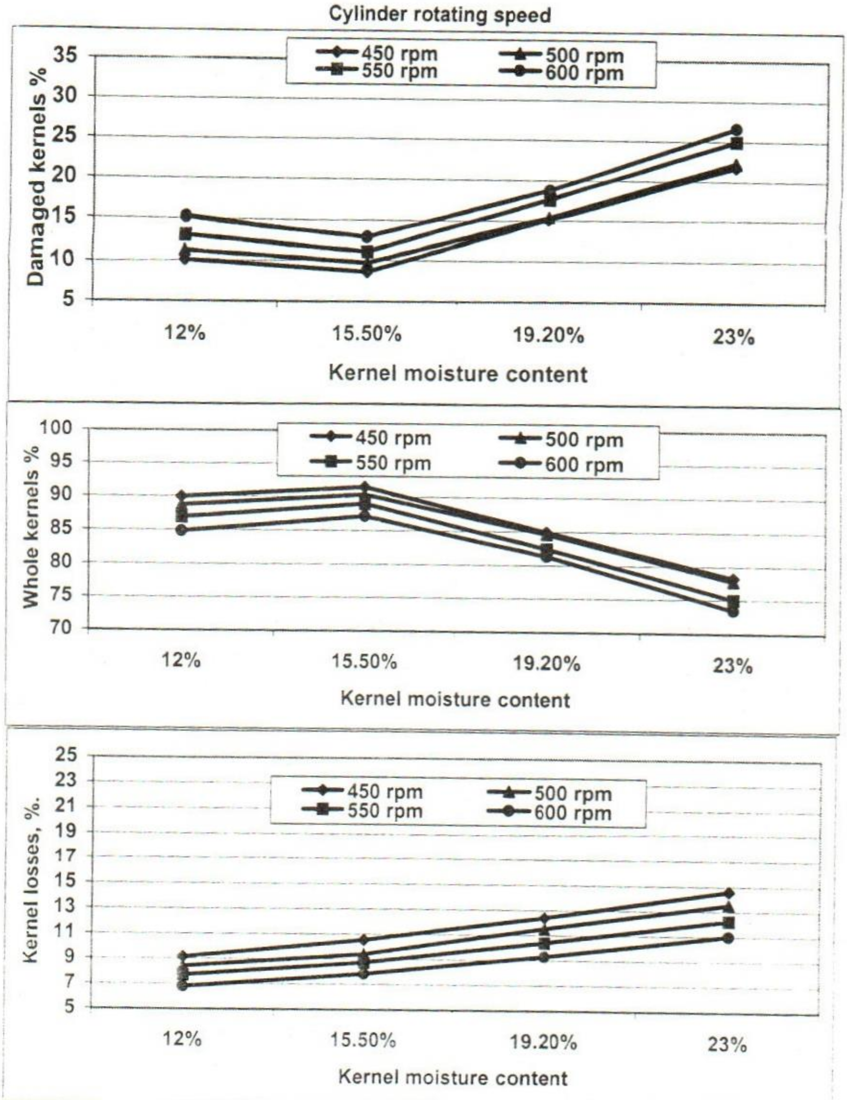

Fig. 6: Effect of cylinder rotating speed and kernel mositure content on the damaged kernels, whole kernels and kernel losses

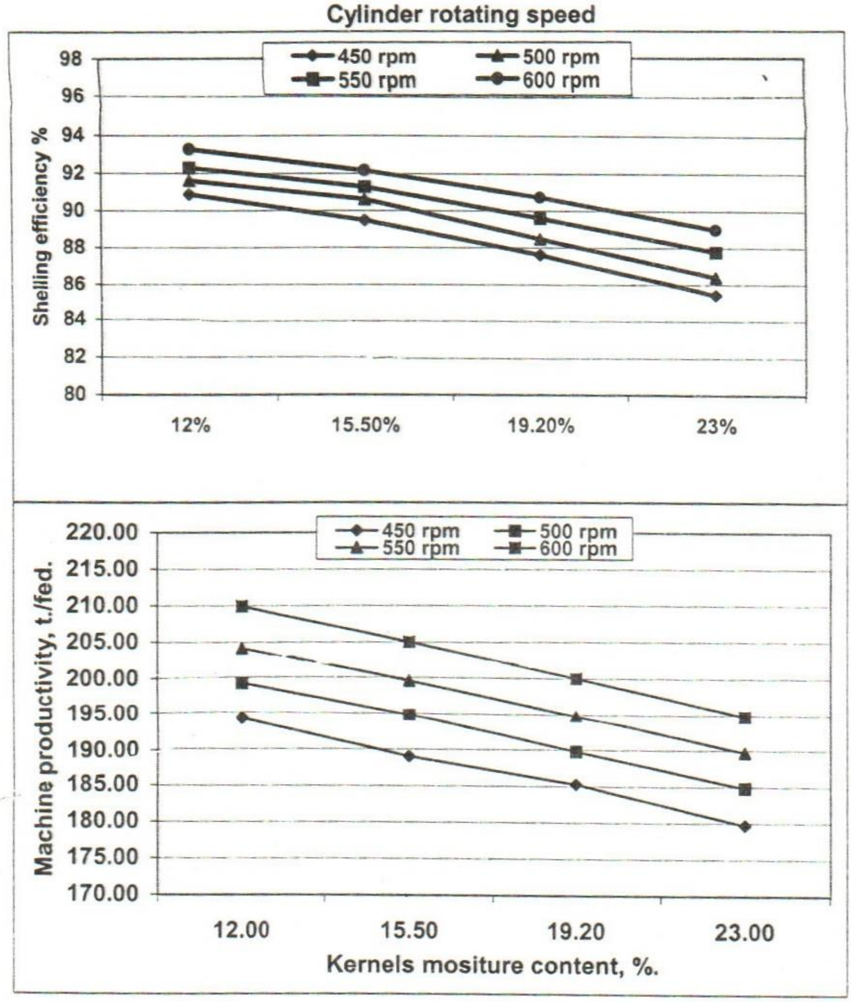

Fig. 7: Effect of kernel moisture content and cylinder rotating speed on the shelling effeciency and machine productivity

where:

Cc = concave clearance, mm;
Cs = cylinder speed, rpm;
m.c= corn kernels moisture content, %.

SUMMARY AND CONCLUSIONS

A simple prototype of corn sheller was investigated and the conclusion of this study could be summarized as follows:

1. The kernels moisture content had positive effects on broken kernels and kernel losses percentage and negative effects on shelling efficiency and machine productivity.
2. The concave clearance had positive effects on whole and kernel losses percentage and negative effects on broken kernels, shelling efficiency and machine productivity.
3. The cylinder speed had positive effects on broken kernels, shelling efficiency and machine productivity and negative effects on the whole and kernel losses percentage.
4. The suitable level of kernels moisture content during shelling operation was 15.5% with cylinder speed of 450 rpm and concave clearance of 50mm which reduced the broken kernels up to 6.5% and increased the whole kernels up to 93.5%.
5. The least percent of kernel losses of 4.6 % and the highest shelling efficiency of 95.4 % and sheller productivity of 215.5 kg / h were found at concave clearance of 30 mm, cylinder speed of 600 rpm (12.6 m/s) and kernels moisture content of 12 %.

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تطوير وتقيم آلة ميكانيكية لتفريط الذرة

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تعتبر عملية تفريط الذرة من أهم عمليات ما بعد الحصاد وهى تجرى يدويا في مصر. والتفريط اليدوي عملية بطيئة جدا وتحتاج إلي وقت كبير وعمالة كثيرة ولكنها تعطى أقل نسبة فقد وتلف للحبوب اذا ما قورنت بالتفريط الآلي . لذلك هذه الدراسة تهدف إلي تطوير وتصنيع نموذج لآلة تفريط الذرة يناسب تفريط معظم الأصناف بأقل نسبه تلف وفقد للحبوب وأيضا تناسب المزارع الصغيرة . تم تطوير وتصنيع هذه الآلة بورشة قسم الأراضي والمياه شعبة االميكنة الزراعية بكلية الزراعة- جامعة قناة السويس وتم اختيار الآلة والحصول على النتائج التالية :-

١- زيادة نسبة المحتوى ألرطوبى لحبوب الذرة أدى إلى زيادة نسبة الكسر والفقد فى الحبوب ونقص نسبة الحبوب السليمة وكفاءة التفريط.

٢- زيادة خلوص الصدر أدى إلي زيادة نسبة الحبوب السليمة و الفقد في الحبوب ونقص في نسبة الحبوب المكسورة وأيضا كفاءة التفريط.

٣- زيادة السرعة ألدورانية لاسطوانة التفريط أدى إلي زيادة نسبة الكسر في الحبوب وزيادة كفاءة التفريط ، وأيضا أدى إلي نقص نسبة الحبوب السليمة ونسبة الفقد في الحبوب.

٤- انسب مستوى للمحتوى الرطوبى للحبوب كان ١٠,٠ % مع سرعة دورا نية لاسطوانة التفريط ٤٥٠ لفه / دقيقة (٩,٤ متر/ ث) وخلوص بين الصدر والاسطوانة قدره ٥٠ مم حيث نقصت نسبة الكسر في الحبوب إلي ٦,٥ % وزادت نسبة الحبوب السليمة إلي ٩٤,٥% .

٥- اقل نسبة فقد في الحبوب (٤,٦ %) ، أعلى كفاءه تفريط (٩٥,٤ %) وأيضا أعلى إنتاجية (٢١٥,٥ كج / ساعة) وجدت عند نسبة محتوى رطوبي قدره ١٢ % وسرعة دورا نية لاسطوانة التفريط ٦٠٠ لفه / دقيقة (١٢,٦ متر / ث) وخلوص بين الصدر و الاسطوانة قدره ٣٠ مم.

٦- عملية ضبط السرعة ألدورانية لاسطوانة التفريط وأيضا الخلوص بين الصدر و الاسطوانة يعتمد على الغرض من عملية التفريط . فإذا كان التفريط لإنتاج تقاوي الحبوب المخصصة للزراعة فإن أنسب سرعة دورا نية هي ٤٥٠ لفه / دقيقة (٩,٥ م / ث) وانسب خلوص هو ٥٠ مم حيث نقصت نسبة الحبوب المكسورة وزادت نسبة الحبوب السليمة .

٧- إذا كان الغرض من عملية التفريط للاستخدام المحلي وتغذية الحيوانات ، فإن انسب سرعة دورا نية هي ٦٠٠ لفه / دقيقة (١٢,٦ م / ث) ، وأنسب خلوص هو ٣٠مم حيث نقصت نسبة الفقد في الحبوب وزادت كفاءة التفريط.