Zagazig J. Agric. Res., Vol. 34 No .(6) 2007 **1183-1201**

DEVELOPMENT OF AN EQUIPMENT FOR CORN SHELLING

Hassan, M. A., M.K. Abd-El Wahab, M. A. El-Shazly, and Hanan, M. El Shal
Agric. Eng. Dept., Fac. of Agric., Zagazig Univ., Zagazig, Egypt.

Accepted 26/8/2007

ABSTRACT: A Pakistan corn shelling machine was developed to suit the Egyptian corn varieties and evaluated its performance under different operational conditions to select the optimum conditions for shelling operations of white and yellow corn. Different measurements were achieved included the total grain damage, total grain losses percentage as well as shelling efficiency, sheller productivity (Mg/h) fuel consumption (Lit/h) power requirement (kW), energy requirement kW.h/Mg and costs, the experiments were conducted at four levels of grain moisture contents of 16, 18, 20 and 22% three concave clearances of 35, 40and 45 mm and four drum speeds of 400, 500, 600 and 700 rpm. (5.03, 6.29, 7.54 and 8.80m/s, respectively), the results indicated that increasing drum speed and decreasing the concave clearance tends to increase the total damage, and shelling efficiency also increase the percentage of total losses at all grain moisture contents for shelling white and yellow corn. The proper conditions for shelling white corn are at drum speed of 500 rpm (5.03 m/s), moisture content of 20% and concave clearance of 40 mm, for yellow corn are at drum speed of 500 rpm (5.03 m/ s),moisture content of 18% and cylinder concave clearance of 40 mm.

Key Words: Shelling, concave clearance, free grain, shelling efficiency, invisible damage.

INTRODUCTION

Corn crop is considered one of the most important grain crops in Egypt. It is used in human feeding, industrial aspects for producing corn oil, starch and dry food for animal. The cultivated area ranges between 1.9 to 2.0 million feddans yearly with total productivity of about 7.6 million ton of grains. Recently, the government tends to enlargement the growing corn to satisfy the shortage of the wheat production and try to make the self sufficiency for bread by mixing corn with wheat with a percentage of 20%. Harvesting, husking and shelling corn in Egypt are essentially carried out manually till now. These operations are laborious and time consuming with low production. Corn shelling is an important process after harvesting compared with other operations.

The kernels damage in maize shelling by rasp-bar cylinder is affected by grain moisture content, cylinder speed, and concave clearance stated by Fouad *et al.* (1981).

The percentage of split bean and fine material increased as the impact velocity increased, and as the seed moisture content decreased from 17 to 8 percent found by Paulsen *et al.* (1981).

The effect of threshing action of the drum on the plant mass is accompanied by repeated impact-on the latter and its deformation in the interspace of the drum and the concave stated by Klenin *et al.* (1985).

It was observed for axial flow peg tooth thresher on chickpea that cylinder speed, feed rate and cylinder concave clearance affected the thresher performance in terms of grain damage, total machine losses, threshing and cleaning efficiencies tested by Anwar (1987).

The shelling operation depends largely on the impact force and partially on friction force. The friction coefficient had small effect, so the impact surface must be made form rigid and rough materials found by Tayel and Khairy (1988).

The effect of moisture content on rupture force of corn kernels was studied. The result shows that the force required to initiate rupture decreased as the moisture content increased studied by Abdel-Mageed and Hemeda (1991).

The drum speed of 13.75 m/ s (350 rpm) is recommended for threshing palady bean crop as it requires both minimum losses and power reported by Abo El-Naga (1995).

The effect of some factors on the productivity of a locally manufactured rasp-bar corn sheller was studied by Mettwalli *et al.* (1995). They concluded that the unshelled grain losses was 2.81%, the visible damage was 5.71% the invisible damage was 7.19% and the cost per unit weight of production was about 7.5 l.E/Mg furthermore, the previous criteria were at optimum condition included cylinder speed of 10.26 m/s, moisture content of 20% (W.B.) and clearance ratio ranged from1.8 to 2.1.

The drum speed of 11.09m/s (530rpm) and seed moisture content of 9% are recommended for threshing chickpeas crop it in recorded both minimum losses and energy (3.07% and 25.80 kW.h/fed), respectively (Ali, 1998).

The suitable kernel moisture content for harvesting and corn shelling ranged from (26.16% to 22.22%), drum speed ranged from 600-700 rpm. (9.42-10.99 m/ s), forward speed was 2.1-3.3 km/ h drum clearance 20/ 40 mm (Ebtsam 2000).

The suitable level of kernels moisture content during shelling operation was 15.5% with cylinder speed of 450 rpm and concave clearance of 50 mm which reduced the broken kernels up to 6.5% and increased the whole kernels up to 93.5% (Mady, 2004).

The objectives of this research are

1- Developing an imported Pakistan corn shelling machine to be suitable for shelling the Egyptian corn varieties.
2- Optimizing some operating and engineering parameters (drum peripheral speed, grain moisture content, and concave clearance) affecting the performance of the sheller during shelling different varieties of corn.
3- Comparing the use of developed shelling machine with the original sheller with respect to grain losses, damage, shelling efficiency, power requirements and also from the economic point of view.

MATERIALS AND METHODS

The main experiments were carried out during the agricultural seasons of 2005-2006 at kafer El-Hamam, research station, Sharkia governorate to develop Pakistan corn shelling machine to suite shelling Egyptian corn varieties and to improve its performance, and compare its performance with the original machine.

Materials

Crop

Yellow corn (Dent corn ear single hybrid 155)

White corn (Dent corn ear single hybrid 10)

Tractor

Naser tractor, with an engine power of 47.8 kW, PTO speed of (540rpm) was used in this study.

The Original Corn Sheller

Pakistan corn sheller machine as shown in Fig. 1 consists of an steel drum with length of 610 mm and diameter of 170 mm. the iron drum with spike teeth rested on two bearings fixed on the frame, concave have diameter holes of 12 mm. and the feeding was manual through the upper opening, the machine is operated by means of machine pulley and belts powered from tractor PTO.

The Modified Corn Shelling Machine

The corn sheller was developed as follows:

1- Replace the original concave by a new concave of 3 mm thickness, round holes of 18 mm slots to change the clearance between drum and concave, as shown in fig. 2.
2- Modify feeding gate to make it more smooth in feeding operation, as shown in fig. 2.
3- Replace the outlet sieve by another one with holes of 18 mm diameter, as shown in fig. 2.
4- Modified the original concave by opening slots to make it easier to change the clearance between drum and concave.

Methods

The developed corn sheller was tested to study some operational factors affecting shelling operation as follows:

1- Drum speeds of 400 (5.03), 500 (6.29), 600 (7.54) and 700 (8.80) rpm (m/s).
2- Concave clearances of 35, 40 and 45 mm.
3- Grain moisture contents of 16, 18, 20 and 22%.

The effects were studied at the above mentioned factors on the grain losses%, grain damage%, shelling efficiency %, machine productivity Mg/h, specific energy requirement kW.h/Mg and costs. LE/ Mg.

Measurements

Determination of grain damage

1- Visible grain damage:

The damaged grains were separated by hand and weighted then estimated as a percentage as follows:

$$S_d = \frac{W_d}{W_s} x100$$

Where

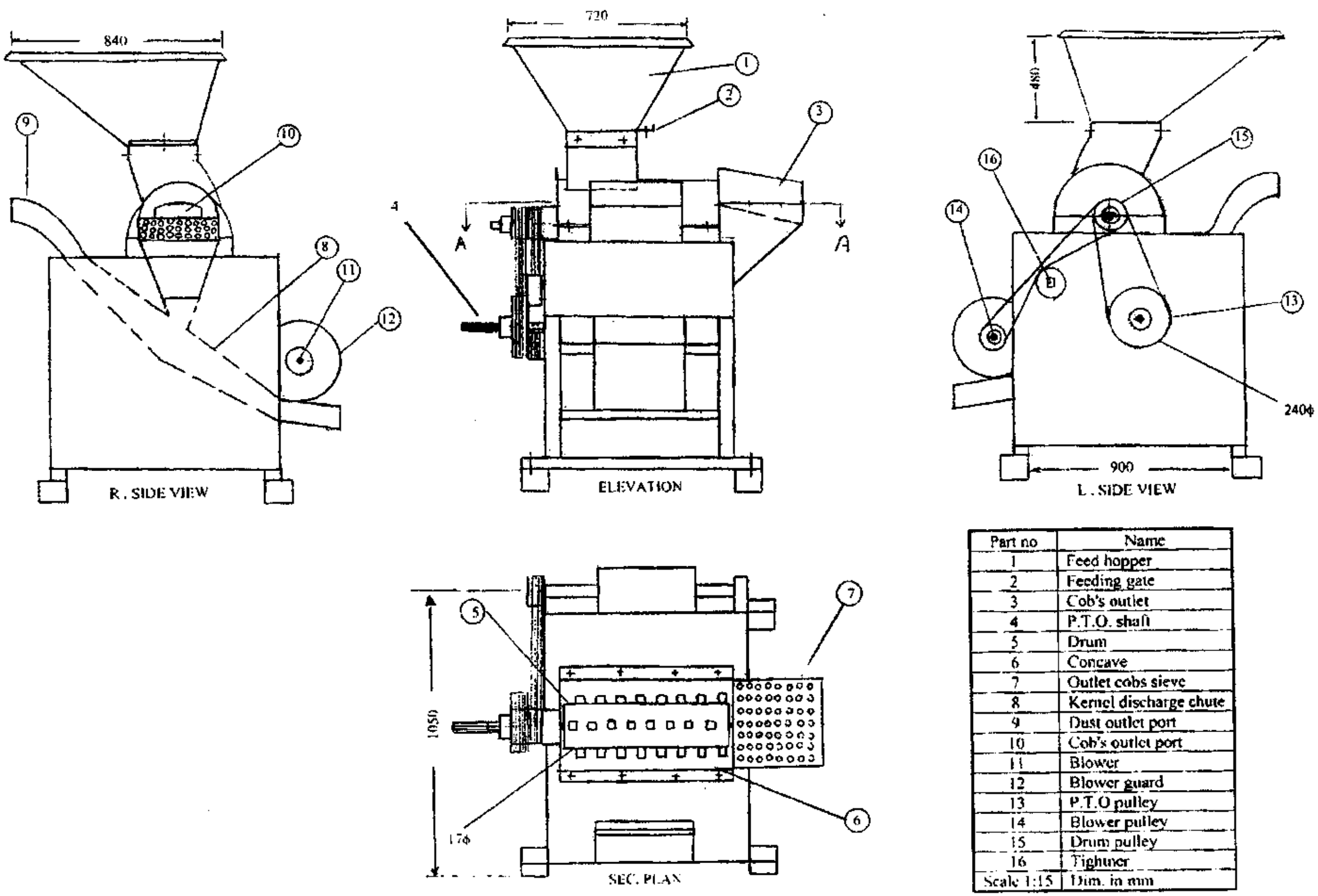
S_d = grain damage, %
W_d = mass of damage grains, g
W_s = total grain mass (100 g)

2- Invisible grain damage tested by germination the percentage of the invisible grain damage was calculated as follows:

$$\text{Invisible damage (\%)} = \frac{a}{b} x100$$

Where

a: number of ungerminated grains from the samples taken after machine shelling operations.
b: total number of grains in the sample.

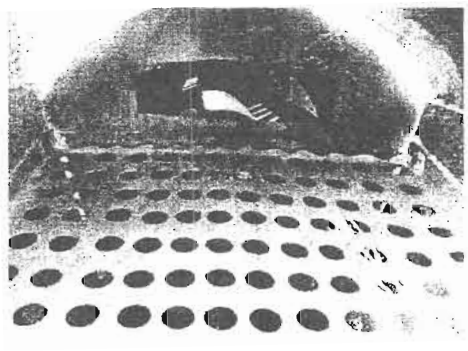


Part no	Name
1	Feed hopper
2	Feeding gate
3	Cob's outlet
4	P.T.O. shaft
5	Drum
6	Concave
7	Outlet cobs sieve
8	Kernel discharge chute
9	Dust outlet port
10	Cob's outlet port
11	Blower
12	Blower guard
13	P.T.O pulley
14	Blower pulley
15	Drum pulley
16	Tightner
Scale 1:15	Dim. in mm

Fig. 1. Elevation, right and left side views and sec. plane for corn sheller before development.

The concave

Modified feeding gate.



outlet sieve

Fig. 2. Views of concave, modified feeding gate and outlet sieve after development

Shelling Losses

1- The unshelled grains from the ears were shelled manually after shelling operations and weighted then calculated its percentage as follows:

$$L_k = \frac{W_2}{W_1 + W_2 + W_3} x100$$

Where

L_k = unshelled percentage.

W_1 = mass of shelled grain, kg.

W_2 = mass of unshelled grains, kg.

W_3 = mass of shelled and received at the outlet of cobs, kg.

2- The free grains which found with the cobs were weighted and then its percentage calculated as follows:

$$L_c = \frac{W_3}{W_1 + W_2 + W_3} x100$$

Total losses = $(L_k + L_c)$ %

Shelling Efficiency %

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

$$E = [1 - L_k]\,\%$$

Machine Productivity (Mg/h)

It was calculated as follows

MP = W_t. 3600/ T

Where

T: shelling time in second.

Power Required for Shelling

Estimation of the required power was carried out by accurately measuring the decrease in fuel level in the fuel tank immediately after executing each operation.

The required power (p) was calculated by using the following formula (Barger *et al*., 1963).

$$P = \left[F_c \times \frac{1}{60 \times 60} \right] \times \rho_f \times Lcv \times 427 \times \eta_{th} \times \eta_m \times \frac{1}{75} \times \frac{1}{1.36},\ kW$$

Where

F_c = The fuel consumption, L/h.

ρ_f = The density of fuel, for solar fuel = (0.85 kg/L).

L.C.V= Lower calorific value of fuel, kcal/kg, (average L.C.V. of diesel fuel is 11000 kcal/ kg).

427 = Thermo-mechanical equivalent, kg. m/ kcal.

η_{th} =Thermal efficiency of the engine, (considered to be 30%-35% for diesel engine).

ηm = The mechanical efficiency of the engine, (considered to be 80% for diesel engine).

Energy Requirements for Shelling

Specific Energy requirements was calculated using the following equation:

Specific energy requirements (kW.h/ Mg) =

$$\frac{\text{Required power (kW)}}{\text{Machine productivity (Mg/h)}}$$

Cost Analysis

The shelling cost was determined using the following equation (Awady, 1978).

$$C = \frac{p}{h}\left(\frac{1}{a} + \frac{i}{2} + t + r\right) + (0.9\,w.f.s.) + \frac{m}{144},\ L.E/h$$

Where

C =Hourly cost, L.E/ h

p = Price of the machine, L.E

h = Yearly working hours, h

a = Life expectancy of the machine, year

i = Annual interest rate, %

a = Takes and overhead ratio, %

r = Annual repair and maintenance rate, %

0.9 = Factor accounting for ratio of rated power and Lubrications

w =Engine power, kW

s = Specific fuel consumption, L. kW/ h

f = fuel price, L.E/ L

m =Operator monthly salary, L.E

144 = Monthly average working hours

The operating cost was determined using the following equation

Operating cost, (L.E/ Mg) =

$$\frac{\text{Machine cost, L.E / Mg}}{\text{Machine productivety (Mg / h)}}$$

The criterion cost was determining using the following equation (Awady *et al.*, 1982).

Criterion cost (L.E/Mg) = operating cost (L.E/Mg) +seed losses cost (L.E/ Mg).

RESULTS AND DISCUSSION

The obtained results from shelling white and yellow corn by using corn sheller machine before and after development are summarized under the following main points.

Factors Affecting Total Grain Losses

The total grain losses are expressed as the amount of unshelled grain and free grain losses with cobs. They are highly affected by grain moisture content, drum speed and concave clearance, as shown in figs 3 and 4.

Drum speed

The obtained data in Figs 3 and 4 show that increasing drum speed from 5.03 to 8.8 m/s (400 to 700 rpm) increased the total losses from 15.18 to 24.20% and from 21.98 to 25.90% for shelling white and yellow corn by using corn sheller before and after development at concave clearance 35mm and moisture content of 16% this is due to the increase in free grain losses at the outlet of cobs and increasing of the unshelled grain losses.

Grain moisture content

Results indicated that decreasing grain moisture content from 22 to 16% at concave clearance of 35mm and drum speed of 5.03 m/s (400 rpm) increased the total grain losses from 2.44 to 3.11% and from5.28 to 5.45% by using developed corn sheller for shelling white and yellow corn, due to the unshelled decrease and the free grain losses increase.

Concave clearance

Results show that increasing the concave clearance from 35 to 40 mm decrease total grain losses from 3.11 to 1.95 and from 5.28 to 5.20% at drum speed of 5.03m/s (400 rpm) and grain moisture content of 16% by using the developed corn sheller for shelling white and yellow corn. This is attributed to the high decrease occurred in the percentage of free grain losses escaped with cobs.

Factors Affecting Total Grain Damage

The total grain damage are expressed as the visible and invisible damage of the shelled grains and it is obvious from the obtained results that they are affected by grain moisture content, drum speed and concave clearance as shown in figs 5 and 6.

Drum speed

Obtained data show that total grain damage increases from 6.71 to 8.20% and from 6.71 to 8.20% as drum speed increase from 5.03 to 8.8m/s by using the developed corn sheller for shelling both white and yellow corn at the different operating conditions. This is due to the great bulk material at high drum speed which cause high friction and pressure on the grain which in turn will cause more damage.

Grain moisture content

Figs 7 and 8 indicated that the total grain damage decreased from 6.20 to 4.20% and from 6.40 to 4.90% with decreasing grain moisture content to a limited values of 20, 18% after which it tends to increase during shelling white and yellow corn, respectively by using developed corn sheller. This result may be attributed to the fact that the grain is soft at the higher grain moisture content levels and more brittle at lower moisture content levels. So it could damaged easily by shelling.

Concave clearance

results indicated that increasing concave clearance from 35 to 45 mm decreased the total grain damage from 10 to 8.62% and from 34.33 to 25.51% for shelling white and yellow corn by using corn sheller before development and also decreased the total grain damage from 6.71 to 4.30% at grain moisture content of 16% and drum speed of 5.03 m/s (400 rpm), for shelling while corn and decreased from12.8 to 6.20% for shelling yellow corn, by using developed corn sheller. This is because of the decrease of friction between kernels on the higher concave clearances.

Shelling Efficiency

Shelling efficiency increased by increasing drum speed and decreasing concave clearance and grain moisture content. The use of the developed corn sheller increased shelling efficiency by 5.5 and 8% for shelling white and yellow corn respectively at drum speed of 6.29 m/s (500 rpm), concave clearance of 35mm and grain moisture content of 16%, due to the unshelled grain losses decreased.

Factors Affecting Machine Productivity

Drum speed

Figs 9 and 10 illustrate that increasing drum speed from 5.03 to 8.8 m/s (400 to 700 rpm), at moisture content of 16% and concave clearance of 35 mm, increased productivity from 2433 to 3521 Mg/ h and from1831 to 2030 Mg/h for shelling white and yellow corn, respectively, by using developed corn sheller, this is attributed to the high impacting force between ear and drum.

Grain moisture content

Results show that the productivity increased from 1680 to 2433 Mg/h and from 1120 to 1831 Mg/ h, by decreasing moisture content from 22 to 16% for shelling white and yellow corn respectively, by using developed corn sheller, this may be due to the decrease of grain cohesion force.

Concave clearance

Results show that by increasing the concave clearance the productivity decrease it is also noticed that the productivity by using developed corn sheller is three times the productivity by using corn sheller before development, due to increase of the concave holes diameter from 12mm to 18mm.

Fuel and Power Consumption

Obtained data show that the fuel and power consumption increased with increasing drum speed and grain moisture content while it increased by decreasing concave clearance by using developed corn sheller for shelling white and yellow corn at different operational conditions.

Energy Requirement

Results show that increasing drum speed, concave clearance and moisture content increased the energy requirement at the different operational conditions.

The energy required at the optimum recommended point (drum speed of 6.29m/s (500 rpm), concave clearance of 40mm and grain moisture content of 18% for white corn and 20% for yellow corn) for shelling white and yellow corn is 2.60, 4.65 kW.h/Mg, respectively.

Cost Requirements for Corn Shelling

Results show that the criterion cost decreased by decreasing moisture content and drum speed while it decreased by increasing concave clearance.

The cost requirements at the optimum recommended point (drum speed of 6.29m/s (500 rpm), concave clearance of 40mm and grain moisture content of 18% for white corn and 20% for yellow corn) for shelling white and yellow corn is, 60.4 and 125.31 L.E/ Mg respectively.

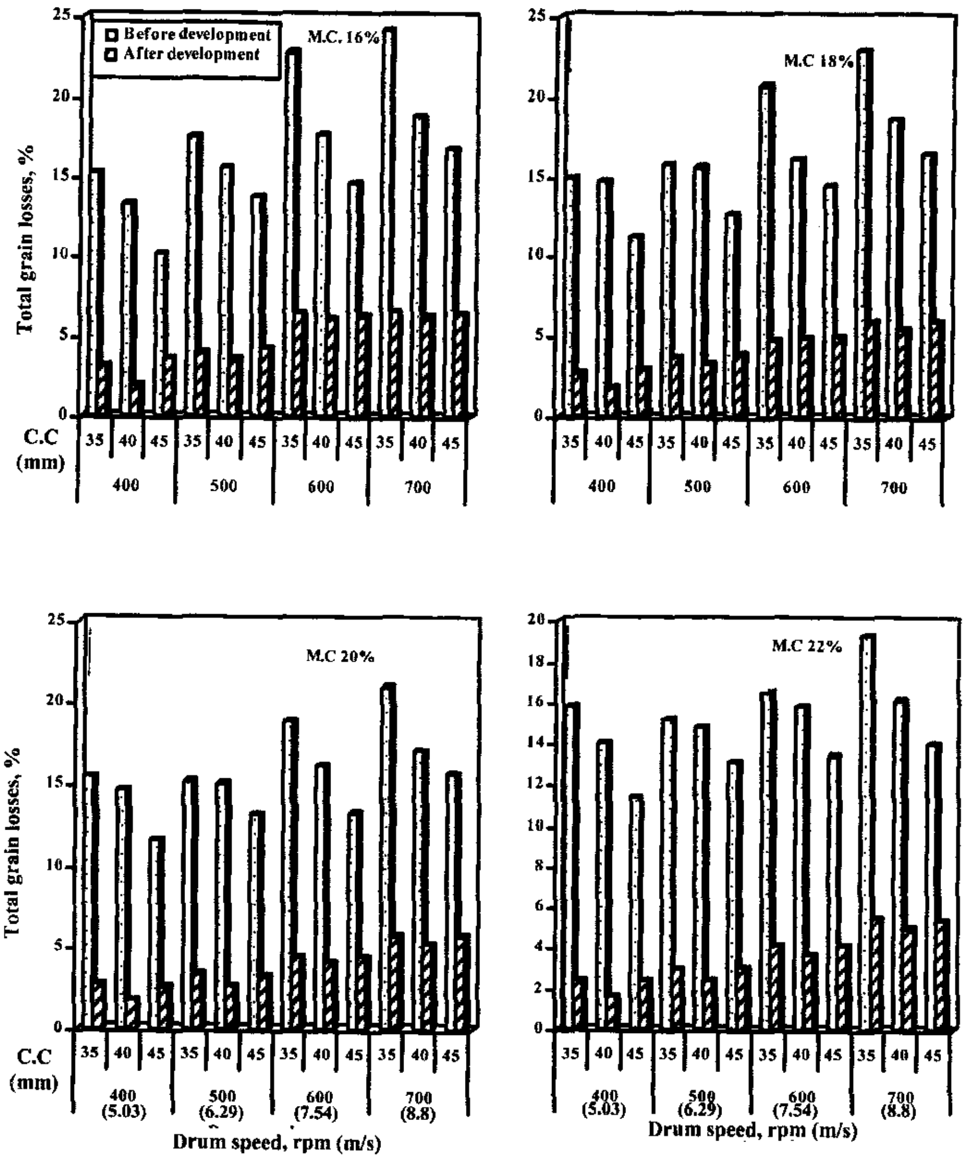


Fig. 3. Effect of drum speed and cylinder concave clearance (C.C mm) on total grain losses using corn sheller before and after development for shelling white corn at different grain moisture contents.

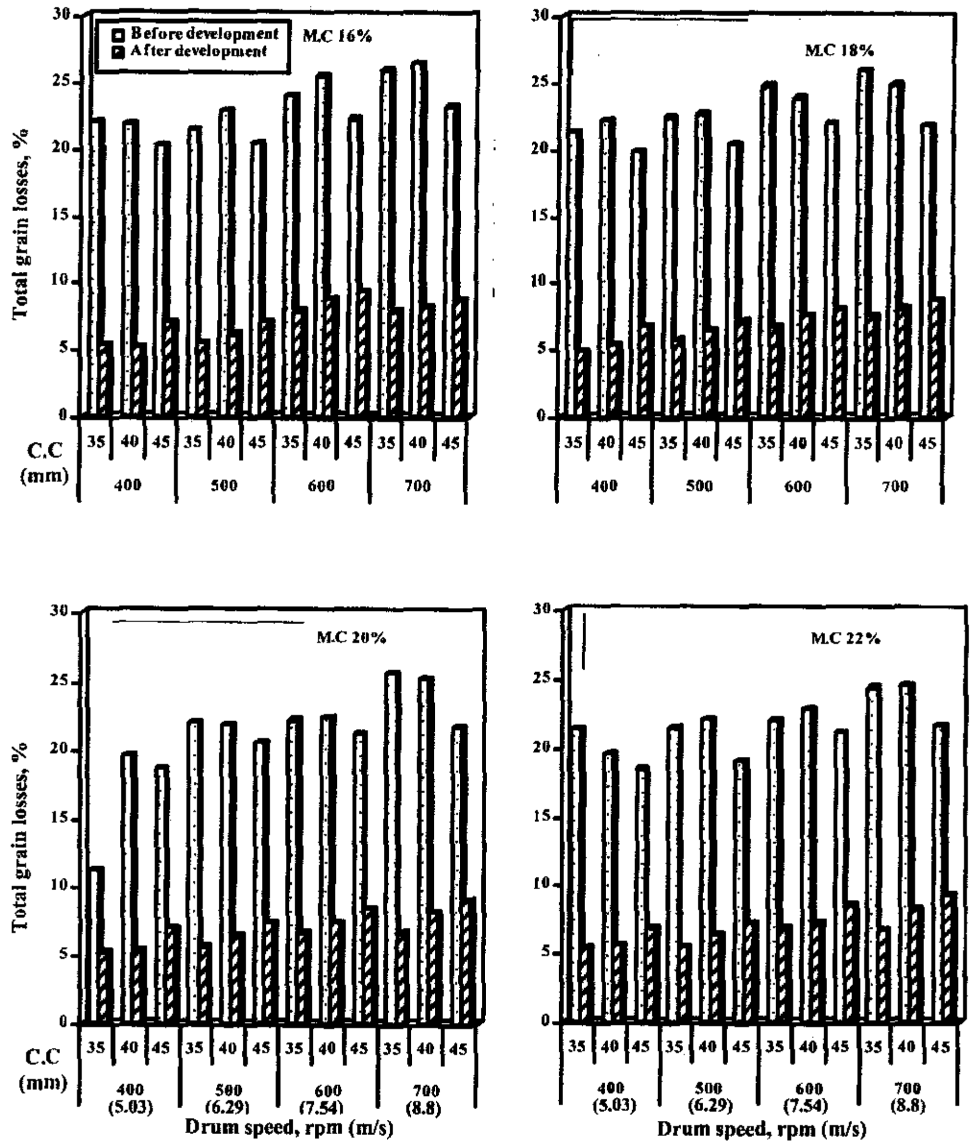


Fig. 4. Effect of drum speed and cylinder concave clearance (C.C. mm) on total grain losses using corn sheller before and after development for shelling yellow corn at different grain moisture contents.

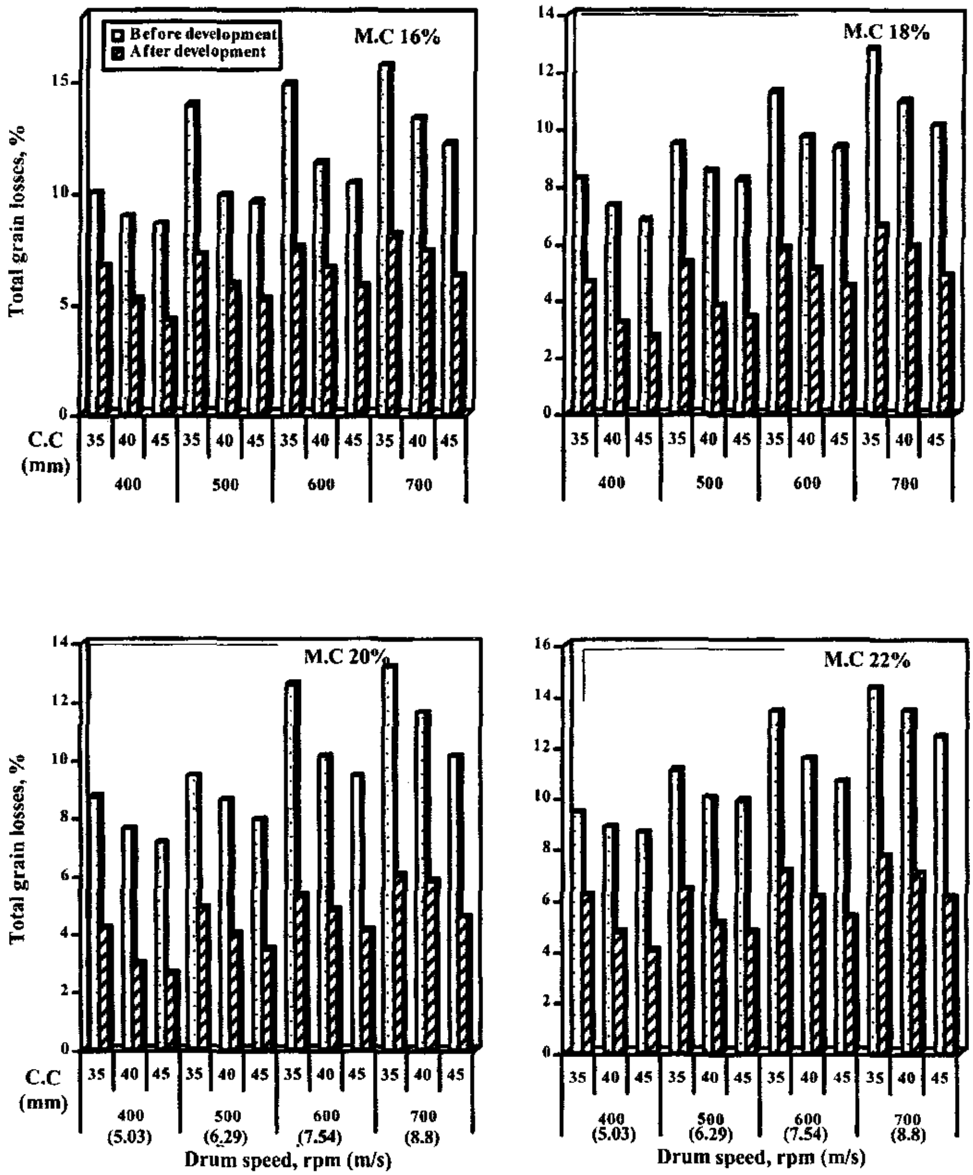


Fig. 5. Effect of drum speed and cylinder concave clearance (C.C. mm) on total grain damage using corn sheller before and after development for shelling white corn at different grain moisture contents.

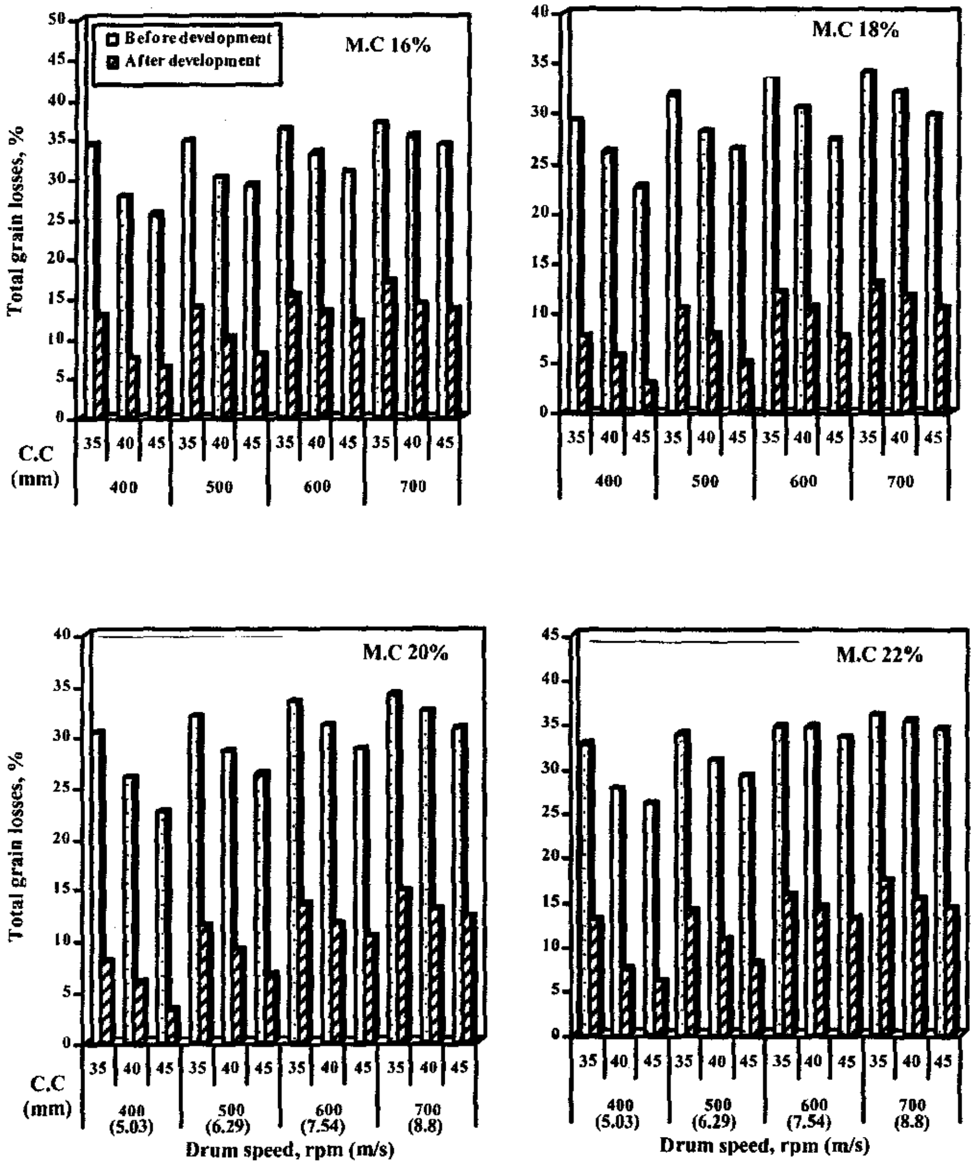


Fig. 6. Effect of drum speed and cylinder concave clearance (C.C. mm) on total grain damage using corn sheller before and after development for shelling yellow corn at different grain moisture contents.

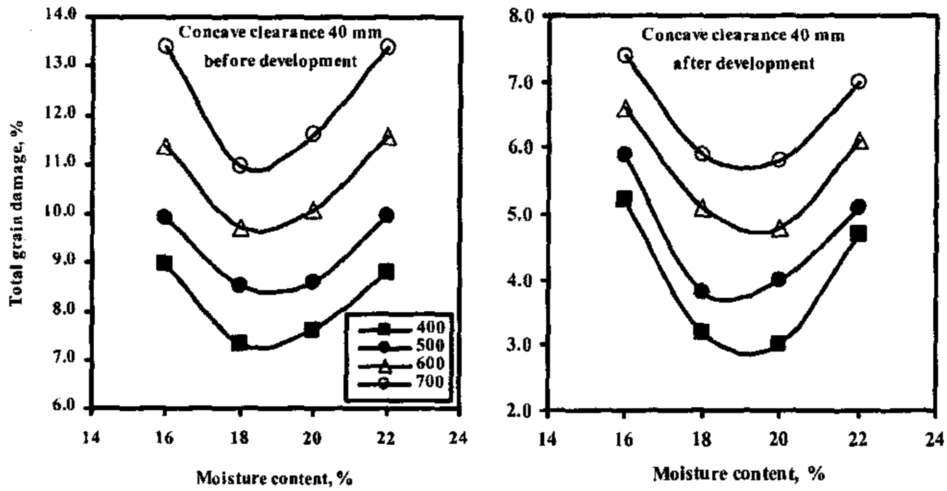


Fig. 7. Effect of grain moisture content and drum speed on total grain damage (%) using corn sheller before and after development for shelling white corn at concave clearance 40mm.

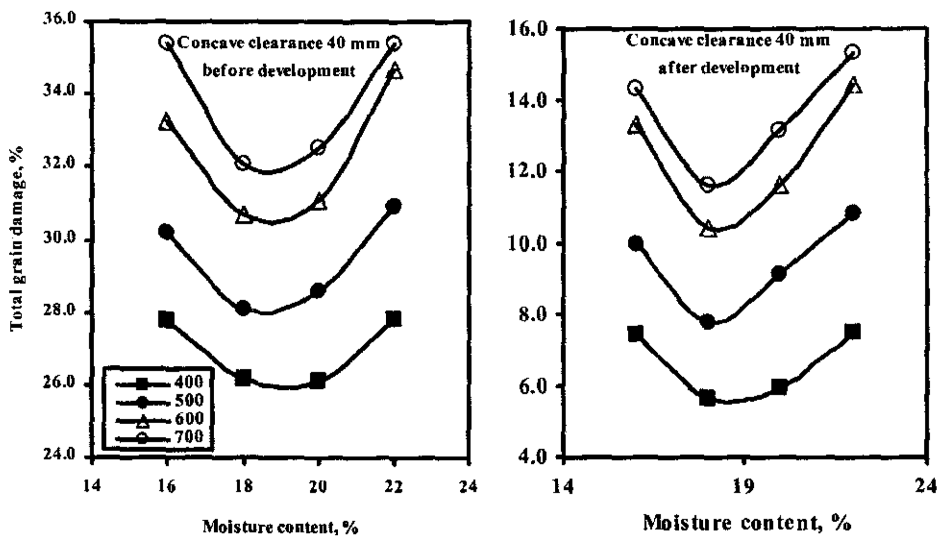
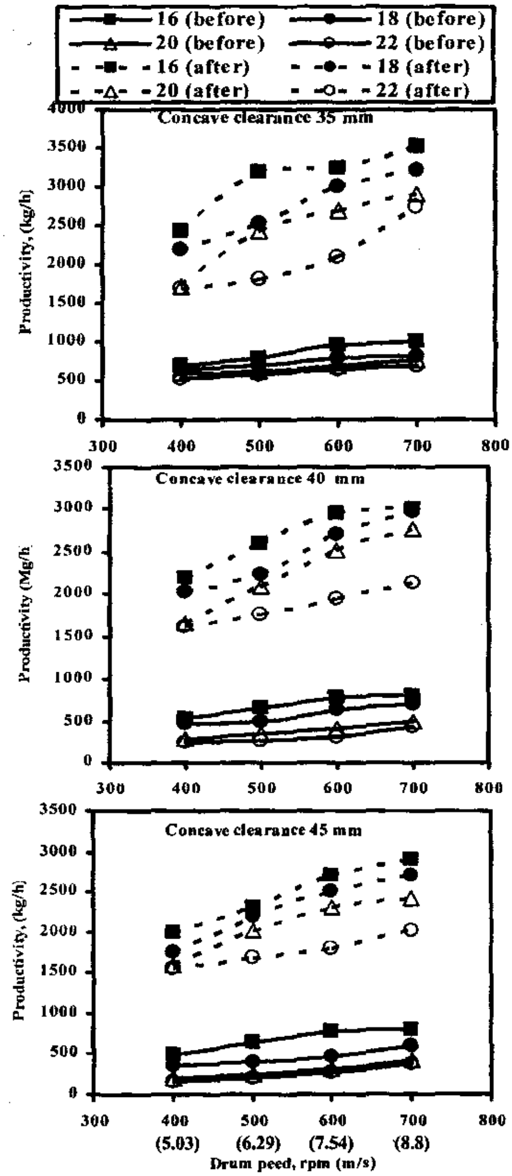


Fig. 8. Effect of grain moisture content and drum speed on total grain damage (%) using corn sheller before and after development for shelling yellow corn at concave clearance 40mm.



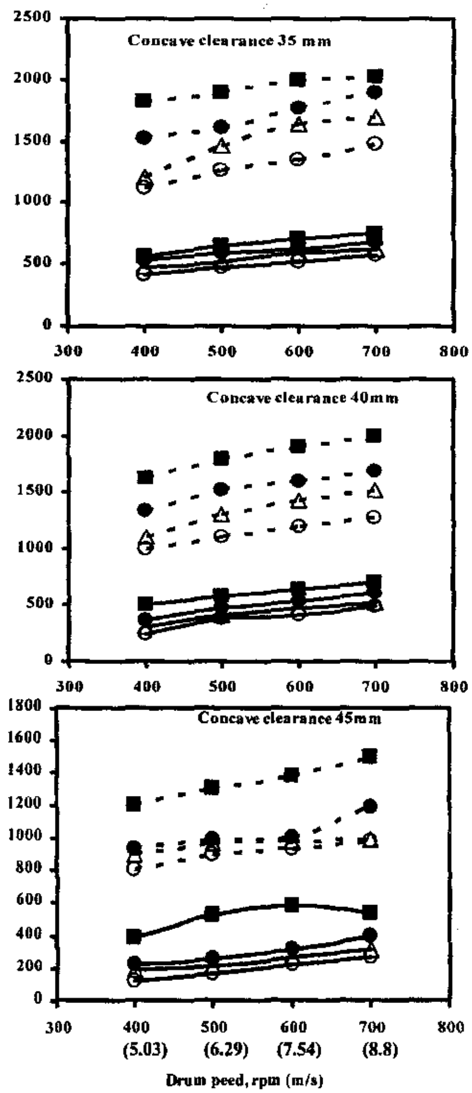


Fig. 9. Effect of grain moisture content and drum speed on machine productivity using corn sheller before and after development for shelling white corn at different concave clearances.

Fig. 10. Effect of grain moisture content and drum speed on machine productivity using corn sheller before and after development for shelling yellow corn at different concave clearances.

CONCLUSION

The main results can be summarized as follows:

1- The use of the developed corn sheller for shelling both white and yellow varieties achieved the following advantages:
  - Increasing shelling, efficiency and productivity.
  - Reducing total grain losses and total grain damage.
  - Decreasing energy requirements and criterion cost.

2- The results recommended the use of the developed corn sheller machine for shelling both white and yellow verities at drum speed of 6.29 m/s (500 rpm), cancave clearance of 40 mm and grain moisture content of 18% and 20% for white and yellow corn respectively to achieve high shelling efficiency, low grain losses and grain damage. Low energy consumption and low operational cost.

REFERENCES

Abd El-Mageed, H.N., and M.A. Hemeda. 1991. Effect of some physical and chemical properties on rupture force of corn kernels Misr. J. Agric. Eng., 8(2): 110-119.

Abo El-Naga, M.H. 1995. A study of mechanization of balady bean on small holdings. Ph. D. thesis, Fac. Of Agric. Zagazig univ.

Ali, M.M. 1998. Study on the mechanization of chickpea crop production under Egyptian conditions. M.Sc. Thesis, Agric. Eng. Dept. Fac. Agric. Zagazig university.

Anwar M.T. 1987. Field performance evaluation of chickpea thresher in Pakistan. M. SC., Asian institute of technology, Bangkok, Thailand.

Awady, M.N. 1978. Tractor and farm machinery. Txt bk., col. Agric Ain Shams. V: 164-167.

Awady, M.N., E.Y. Ghoniem, and A.L. Hashish 1982. A critical comparison between wheat combine harvesters under Egyptian conditions. Res. Bul. No. 1920. Ain Shams. V: 1-13.

Barger, E.I., B.L. Eohl, W.M. Carleton, and E.G. Mekibben. 1963. Tractor and their power unit. 2nd ed., Wiley and sons. Inc., NY.

Fouad, H., M.N. Awady, G.B., Hanna, and M. Abou El-Kheir. 1981. Optimal operation conditions for shelling maize with a rasp-bar cylinder. J. Col. Agric. Unir. Riyadh,3: 31-42.

Klenin, N. I., I. F. Popov, and V.A. Sakon. 1985. Agricultural machines. Amerind publishing Co. Prt. ltd., New Delhi.

Mady, M.A. 2004. Development and evaluation of a power operated corn sheller. J. Agric. Sci. Mansoura univ., 29 (8): 4613-4628.

Metwalli, M. M., M.A. Helmy, S. M. Gomma, and M. E. Badawy. 1995. Evaluation of some parameters affecting corn sheller performance. Misr. J. Agric. Eng., 12(2): 439-455.

Paulsen, M. R., W. R. Nave, and L. E. Cray. 1981. Soybean quality as affected by impact damage. Trans. Of the ASAE, 24(6): 1577-1582.

Tayel, S.A., and M.F.A. Khairy. 1989. A study on some design criteria of sunflower shelling machine. Misr. J. Agric. Eng., 5(3): 307-316.

تطوير آلة لتفريط الذرة

محمود عبد العزيز حسن- محمد قدري عبد الوهاب- محمود عبد الرحمن الشاذلي
حنان محمد سعد الدين الشال
قسم الهندسة الزراعية- كلية الزراعة- جامعة الزقازيق

أجريت هذه الدراسة في محطة كفر الحمام- التابعة لمركز البحوث الزراعية سنة ٢٠٠٥-٢٠٠٦

وكان الهدف من الدراسة: هو تطوير آلة تفريط الذرة الباكستانية الصنع لتناسب تفريط الأصناف المصرية وتقييمها للوصول إلى أفضل عوامل التشغيل التي تعطى أعلى كفاءة في الأداء ولقد تم تصنيع صدر درفيل بثقوب قطرها ١٨ مم بدلاً من ١٢ مم وعمل مشقبيات على الجوانب لتغير الخلوص ووضع شبكة بثقوب قطرها ١٨ مم في مخرج القوالح وتعديل فتحة التلقيم حتى تكون إنسيابية الشكل.

وكانت متغيرات الدراسة:

١- أربع سرعات لدرفيل التفريط ٤٠٠ (٥,٣٠)، ٥٠٠ (٦,٢٩)، ٦٠٠ (٧,٥٤)، ٧٠٠ (٨,٨٠) لفة/ دقيقة (م/ ث).
٢- أربع نسب رطوبه للحبوب ١٦، ١٨، ٢٠، ٢٢%.
٣- ثلاثة قيم للخلوص بين الدرفيل والصدر ٣٥، ٤٠، ٤٥ مم وإستخدام في البحث صنفين من الذرة (ذرة بيضاء، وذرة صفراء).

ووجد من النتائج أن الآلة المطورة:

١- تخفض نسبة كبيرة من الفواقد الكيلة للحبوب.
٢- تخفض من الكسر الكلي للحبوب.
٣- تزيد من كفاءة التفريط وإنتاجية الآلة.
٤- تخفض من الطاقة اللازمة لإنتاج الطن من الذرة.
٥- تخفض من التكاليف اللازمة لإنتاج الطن من الذرة.

وهذا لصنفي الذرة تحت الدراسة

وقد تم التوصل إلى أفضل ظروف لتشغيل الآلة المطورة وهى:

● للذرة البيضاء:
- سرعة درفيل التفريط ٥٠٠ لفة/ دقيقة (٦,٢٩ م/ ث).
- نسبة الرطوبة للحبوب ٢٠%.
- الخلوص بين الدرفيل والصدر ٤٠ مم.

● للذرة الصفراء:
- سرعة درفيل التفريط ٥٠٠ لفة/ دقيقة (٦,٢٩ م/ ث).
- نسبة رطوبة الحبوب ١٨%
- الخلوص بين الدرفيل والصدر ٤٠ مم.