EVALUATION OF A PROTOTYPE LOCALLY MANUFACTURED MACHINE FOR THE HUSKING CORN COBS

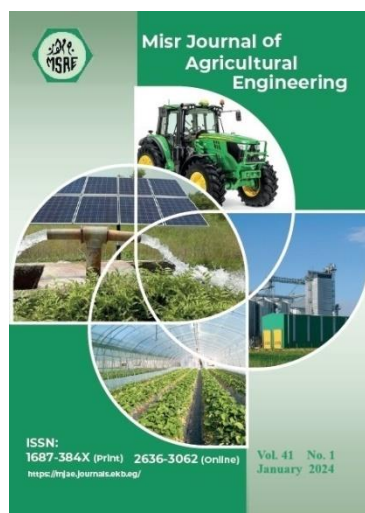## A. A. Abd El-Raheem[1&*], Ahmed T. Imbabi[2] and Mahmoud M. A. Abdel-Azeem[3]

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Keywords:

Maize, Husking, Corn cobs, Rotational speed, Clearance distance.

ABSTRACT

The processes of separating and cleaning the corn cobs from the husks and other impurities is one of the most important post-harvest processes. This machine consists of the following main parts: frame – husking unit – feed opening – power source. Performance of the machine was tested and evaluated to determine the optimal conditions for its operation by studying the following factors: four rotating speeds for husking cylinder, two lengths of husking cylinder and two husking cylinder clearance at two types of corn. The feed opening tilt angle was 144 o. The moisture content in the cobs was 24 %. The evaluation was based on the following parameters: efficiency of the husking process, % - consumed energy, kw h-1 – specific consumed energy, kw /kg h-1– machine productivity, kgh-1 – operation and manufacturing costs, L.E. To improve machines performance (productivity and efficiency) , adjustment was made by narrowing the distance between the protrusions of the husking cylinder from 5 mm to 2.5 mm and increasing the length of the husking cylinder from 100 cm to 200 cm led to increase in the distance traveled by the corn cob over the active part of the machine and thus the increase in the time during , which the cob remains in contact with the surface of the active part.

INTRODUCTION

Maize is considered as one of the most important crops for Egypt and on global scope at is vital source of producing cereals, at it comes in third place as a source of grain production after the wheat and rice crops. In Egypt the maize consumption where green and dry, the average is a cultivated area is about of 2.8 million fed /year , with medium yield of 33 ardeb / fed .On the other hand , in Fayoum the average cultivated area is around 69687 fed/year , with medium yield around of 18.3 Ton / fed **(Egyptian Ministry of Agriculture and Land Reclamation, 2022).** Various physical and mechanical properties of maize husk and grain are essential for the design of machines for processing and handling the grains and their products. The dimensions of a typical maize cob and a maize grain are shown in fig. (1). The longest dimension, L is called length, second

longest dimension, B perpendicular to L is called width and the third longest dimension, T perpendicular to both is called thickness of grain. The force required for detachment of husk and grain from a cob depends upon the direction in which the impact force is applied, the extent of maturity of the grain, the variety of the crop and the biological properties associated with the crop. Due to the fibrous structure of the plant material the strength parameters vary in different directions **(Yang et al., 2016).**

Gorad ,(2017) , reported that after harvesting with sickle and plucking of cob manually, husking of cob is done by hand to remove its outer sheath and further grain is obtained by shelling the cob traditionally, by beating the dehusked cobs with sticks or with fingers or sickle, etc. To overcome this problem of removing its outer sheath and dehusking the cobs this machine was developed to perform both shelling and threshing operations simultaneously. For removal of corn shells and to deseeding of the corns with minimum damage to the corns.
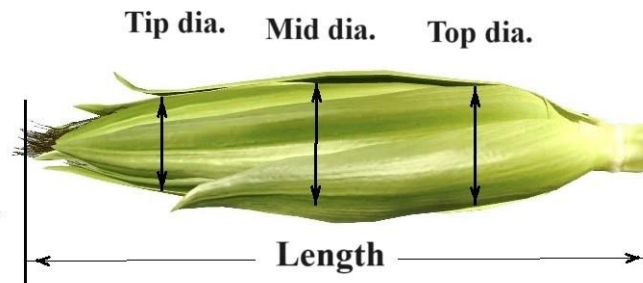

Fig. (1): Corn cob

Klenin et al., (1985) stated that the agricultural product is cleaned and gradded according to various criteria governing each material. These criteria are: geometric size of each particle, their aerodynamic properties, the shape and state of the surface , density and specific weight , electric conductivity and color . **Takawira-Nyakuchena & Mushiri, (2020**) showed that the husker consists of four shafts in parallel. The central ones are those who impel maize cob toward the exit. They have a helical rib. The pitch of the helix impels corn cob towards the exit. A greater pitch means a more exit speed. But corn cob must stay time enough that the husk it is expelled. The outer ones have pins (or studs) projecting from its periphery. These are the responsible of expelling the husk. Fig. (2) illustrated of how corn travel in the machine.
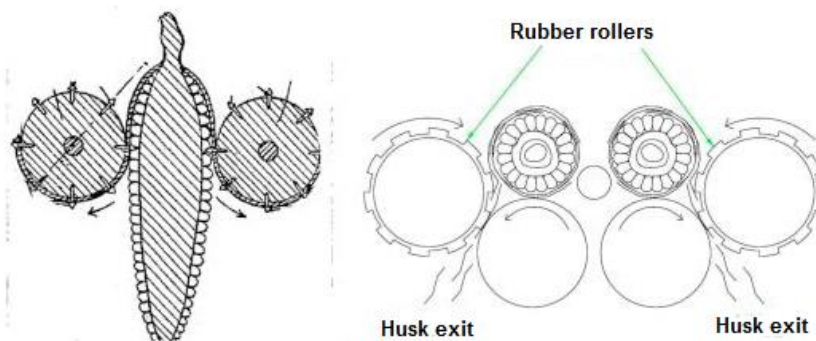

Fig. (2): How corn travel in the machine (Takawira-Nyakuchena & Mushiri,2020)

Jahan et al., (2019) reported that two rubber and two spiral rollers were used for peeling of cobs. The functional parts of the machine are hopper, spiral roller and rubber roller. Four rollers were used for peeling purposes. The working performance of the peeling part of this machine greatly depends on roller materials. As rubber is elastic, the friction coefficient of rubber is big than the metal, so the grasping force and the capacity of tearing husk of maize cobs increase for using rubber roller and the seed broken rate is also low. There is a height difference between the two pair of rollers. Each pair of rollers is in one high and one low-layout. So, the weights of maize cobs have to face a different pressure of the two peeling rollers (**Zhao et al., 2013**). The relative rotation of the two pair of rollers clamped the bracts and torn the maize cobs**.**

Spiral roller can help push the corn cobs to the machine outlet. The rpm of rubber and spiral rollers were almost same which around 1.39-1.43 m s-1. The diameters of spiral and rubber rollers are75 mm and 82 mm, respectively and length of these rollers are 900 mm.The main objective of this work is to manufacture a local machine for husking corn cobs and evaluate the performance of this machine under different operating conditions. **Alexander, (2014)**, stated that a operating parameters (load, gap, roller speeds, and speed differential) of such huskers are largely set experimentally on examining the processed product. The selection of the most appropriate rubber material is frequently chosen on the basis of past experience. **Rajesh et al., (2018)** tested the concave and nut-screw mechanism was supported by two rings made of flat iron placed on either side of rubber roller Average percentage of grain in maize cobs (including husk) varies from 65 to 85 percent depending upon the moisture content of the grain. **Jahan et al., (2019**) reported that for the peeling operation moisture content of maize cobs were taken 20%-24% (wb). The peeling capacities of the manual and power peelings were 87 kg h^{-1} and 1008 kg h^{-1}, respectively when the moisture content of maize cobs was 22% (wb). The highest peeling capacity was 1107 kg h-1 when the moisture content of the maize cob was 20% (wb). The average peeling cobs machine speeds were found to be 1.41 m s^{-1}. The objectives of this study are solve the problem of manual husking with high cost and effort, manufacturing of local machine with available materials instead of importing it at high prices, introducing mechanized operations for post-harvest operations, design machine by using (SolidWorks), studying some operating factors that affect the performance of husking machine which can working on husking maize is suitable to small farm in Egypt and measuring the some properties of corn cobs, husking efficiency , productivity , consumed energy and cost.

MATERIALS AND METHODS

A machine for corn cobs husking was fabricated at a private workshop in the industrial city at Fayoum governorate from local raw materials, during the years of 2019-2020-2021. The main components of the machine were: frame – feed opening – husking unit – power source.

-Frame:
The overall frame is constructed from pipes iron (4.5 ×4.5) cm with dimensions of 112 cm length, 65 cm width and 70cm height , welded together**.** As shown in fig. (4).
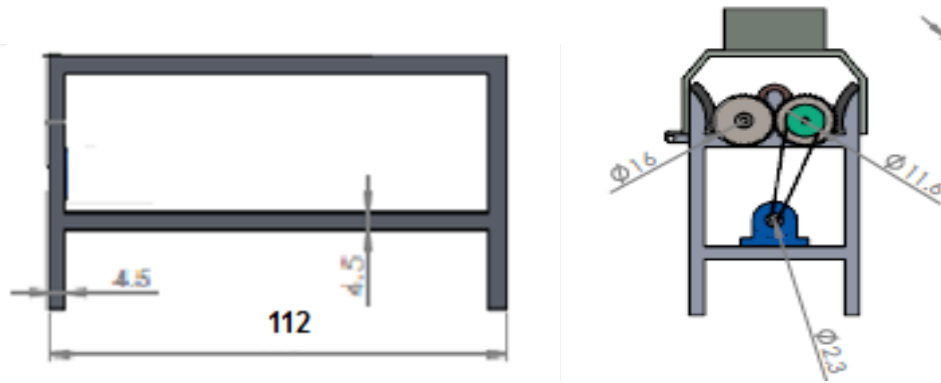
Fig. (4): Side view of the fabricated machine for corn cobs husking

-Feed opening:
The feed opening was installed to feed the corn cobs into the husking machine. The side of this opening slope gradually (144°) to keep the flow of corn cobs on the husking cylinders.

-Husking unit:
Husking process was accomplished by using four rollers (two steel and two rubber, with 100cm length and 15cm diameter for each as shown in Fig.(5).The surface of the first husking steel cylinder is fixed by welding an iron strip (spiral roller with rough surface) , it is coiled in a helical shape along the axis of the cylinder (the dimensions of the coiled spiral strip along axis of the husking cylinder were (180-200) cm length, 1.5 cm width , 6mm diameter ,1 cm thick and distance between its successive rolls were 2.5 - 5 cm. As the second husking cylinder , its outer surface(facing the surface of the first husking cylinder|) was covered with a layer of rubber fixed on it with a thickness of about 2cm and height of 14 cm above steel cylinder .The outer surface of rubber roller is uneven and rough to reduce the cost ,the rubber cylinder is half cylinder .The husking process of the cobs is accomplished by rolling and friction them against the surfaces of the two husking cylinders , so the husks are the squeezed into the clearance of the two cylinders, and then they are removed . The space between the two opposite husking cylinders was adjustable from (zero -1) mm. The mechanism turned at 161, 277, 555 and 812 r.p.m rotational speed for cylinders. The movement of two husking rollers inward , allowing the husks to be pulled through the clearance between two rollers.

Fig. (5) - **Plan of the husking unit cylinders in machine for showing the clearance between the two husking cylinders surfaces.**

- Source of power:

The power source utilized to drive the husking machine was electrical motor (1400 r.p.m and 1.5 hp -1.12 kw) the power from the source was transmitted husking machine by means of pulley and belt. Four pulleys with diameters of 2.3 , 5.8 , 11.6, 20 cm were used to reduce the speed transmitted from the power source (electric motor)1400 r.p.m and reduction ratios were 8.7 , 5.1 , 2.5 , 1.7 to give rotaional speed of 161, 277, 555, 812 r.p.m ,respictively.

-Maize variety:

Experiments were carried out on two types of corn were used from the most common types of corn in Egyptian agriculture namely (White triple hybrid variety 320(1), Baladi (2). Some physical properties of used corn cobs are given in table (1), these properties were related with operating factors optimum. The moisture content of corn cobs at time of experiments was 24.8 %.

-The statistical analysis:

The experiment's data were analyzed as a $2 \times 4 \times 2 \times 2$ factorial experiment in a randomized complete block design with three replications. The best fit sample and multiple regression equations which indicate the effects of different operations variables on the husking parameters were also determined.

Table (1) – Some physical properties of corn cobs.

Parameters	Baladi	Hyrbd
Length, cm	23.6	30.3
Diameter, mm	5.6	11.3
Weight of corn cob, g	686	690
Weight of husk corn, g	54	119.3

-Methods:(Parameters Measurements)

1-A. Machine efficiency:

The machine efficiency (Ɇ) was calculated using the following equations:

$$Ɇ = \frac{W.b.p - W.a.p}{T.p.w} \times 100$$

Where:

Ɇ = Machine efficiency, % ;

W.b.p = Total weight of cobs fed at machine (4 cobs) , g ;

W.a.p = Weight of cobs after peeling, g and

T.w.p = Total peeling weight, g = (W.b.p –W.a.p)+manual peeling **.**

1.B. Husking efficiency:

The husking efficiency (η) was calculated using the following equation**, (Mousa ,2020)**,

$$η = Ɇ \times \left(\frac{w.c.w.h - w.l.g}{w.c.w.h}\right)$$

where:

$η_p$ = Husking efficiency , % ;

Ɇ = Machine efficiency , % ;

w.l.g = Weight of loss grains ,g and

w.c.w.h = Weight of cobs without husk ,g

= W.b.p – (W.b.p – W.a.p)+ manual peeling).

2. Machine Productivity : (P_m)

Time of husking corn cobs process was measured by means of a stop watch. The capacity (productivity) of the machine was calculated as follows ,(**Mousa ,2020**) :

$$P = \frac{W.ac}{T} = \frac{\mu \times W.p}{T}$$

Where:

P=Machine productivity, kg h^{-1};

W.ac = Actual weight of total peeling =$\mu \times$ W.p , g ;

$$\mu = \frac{w.c.w.h - w.l.g}{w.c.w.h}$$

W.p =weight peeling husk, g = W.b.p – W.a.p and

T=Husking time, s.

3.Required power:

The required electric power was measured for husking process. The required electric power was calculated as **Chancellor (1981)** by the following equation:

$$RP = V \times I \times Cos \; Ø$$

Where :

RP= The required power, (w) ;

V= Potential difference, Voltage (1 phase = 220 Voltage);

I= Line current strength (Amperes);

Cos Ø = Power factor, equal 0.64.

A digital clamp meter and voltmeter were used for measuring current intensity and voltage, respectively.

5. Specific consumed energy ：(*SE*)

The specific energy requirement (kw.h / kg) was calculated by using the following equation:

$$SE = Power \; (kw) / Productivity \; (kgh^{-1})$$

6.Costs:

Husking cost was determined using the fixed costs (deprecation, interest on investment, shelter, insurance and taxes) and variable costs (repair and maintenance, electricity and labor) according to **(Srivastava et al., 2006).**

Fixed costs

(a) Depreciation

In calculation of the fixed cost, straight line depreciation is assumed and to calculate the following equation was used(**Hunt, 1995**)

$$D = (P – S)/L$$

where,

D: Depreciation, L.E yr-1;

P: Purchase price of maize peeling machine, L.E;

S : Salvage value was assumed as 10% of purchase price, L.E ,

L : Life of the machine in years.

(b) Interest on investment

Using the following formula interest on investment was calculated (**Hunt, 1995**)

$$I = (P+S) \times I /2$$

Where:

   i: Rate of interest, 10%.

(c) Shelter

Shelter (*S*) is 1% of the purchase price of machine, L.E.

(d) Insurance and taxes

insurance and taxes is 1% of the purchase price of machine, L.E

Total fixed cost (*L.E/ year*) = (*a+b+c*+d)

Variable cost

The variable or operating cost of the machine is reflected by the cost of repair and maintenance, electricity, and labour. These costs increase with increased use of the machine and vary to large extent in direct proportion to hours or days of use per year.

(e) Labor Cost

Two labors are required for operating the machine. One labour is required for delivering maize cob to the hopper and another helps to collect cobs from the outlet part.

$$L = wages\ per\ month \times 12$$

 Where:

   L= Labor cost of year.

(f)Repair and maintenance cost

Maintenance cost is cost of labour required for maintenance should be included as a repair cost (**Rahman et al., 2014**). Repair and maintenance cost (RPM) per hour

RPM = 100% of depreciation L.E/year

   = depreciation (L.E/year) / operating hours per year(h/year)

(g) Electricity

Total electricity cost (L.E/year) = Cost of 1kw.h $\times$ 6$\times$24$\times$12

Total variable cost

$$(L.E\ year) = (e+f+ g)$$

The price of husking unit was 6000 L.E the unit cost was determined using the following equation:

Unit cost = {(Husking costs (L.E h^{-1}) / (Productivity (kg h^{-1})} L.E ton^{-1}

7.Moisture content:

 The moisture content of whole dry corn cobs were using an oven drying at 105 c^{o} 24 hours according to **Ozarslan , (2002)** . This test was repeated five times. The moisture content was determined by using the following equation according to **Kapetanov, et al. (2015)**:

$$M_c = \frac{Mb - Ma}{Ma}$$

Where,

   M_c = Moisture content of the sample, % ;

M_b = Mass of the cob before heat treatment, g;

M_a = (mass of the maize seed +mass of the cob without seed) after heat treatment, g

RESULTS AND DISCUSSION

1.Husking capacity or productivity:

The husking capacity ranged from 16.3 to 1.1 kg/h with cylinder speed of 812 to 161 rpm , cylinder length of 100 to 200 cm, clearance of zero to 1 mm and feed opening angle of 144 degree . The resulted polted in fig (6 and 7) . It could be noticed that the lowest values of husking capacity were obtained at 161 rpm .

As showen in figs.(6 and 7) cleared that the highest productivity was 16.3 kg/h at L_{100}, C_0 and S_{812} and the lowest productivity was 1.1 kg/h at L_{200}, C_1 and S_{161} before modification, while the highest productivity was 9 kg/h at L_{100}, C_0 and S_{277} and the lowest productivity was 1.2 kg/h at L_{200}, C_1 and S_{161} after modification .When the speed increases, the time decreases and the productivity increases , The productivity is inversely proportional to the time.
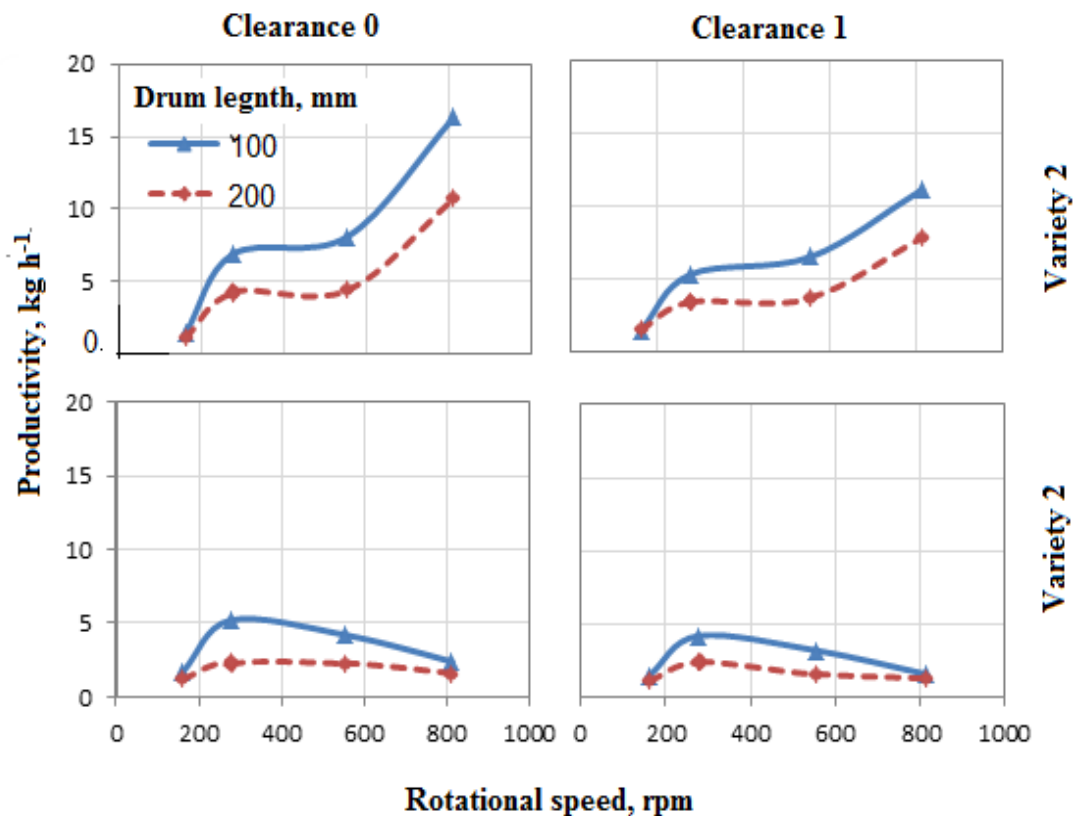
Fig. (6)- The effects of cylinder length, clearance and rotational speed on productivity for variety (1and2) before modification.

2-Husking efficiency (HE)

Figs. (8 and 9) cleared that the highest husking efficiency was 92.9 % at L_{200}, C_0 and S_{277}. The lowest husking efficiency was 14% at L_{100}, C_1 and S_{812}, because it causes damage and shell the grains and, in addition some cobs are not husked due to speed of their movement (jumping)on the surface of the active part of the husking machine before modification , while the highest husking efficiency was 98.8 % at L_{100}, C_0 and S_{277} and the lowest husking efficiency was 37.5% at L_{100}, C_1 and S_{812} .
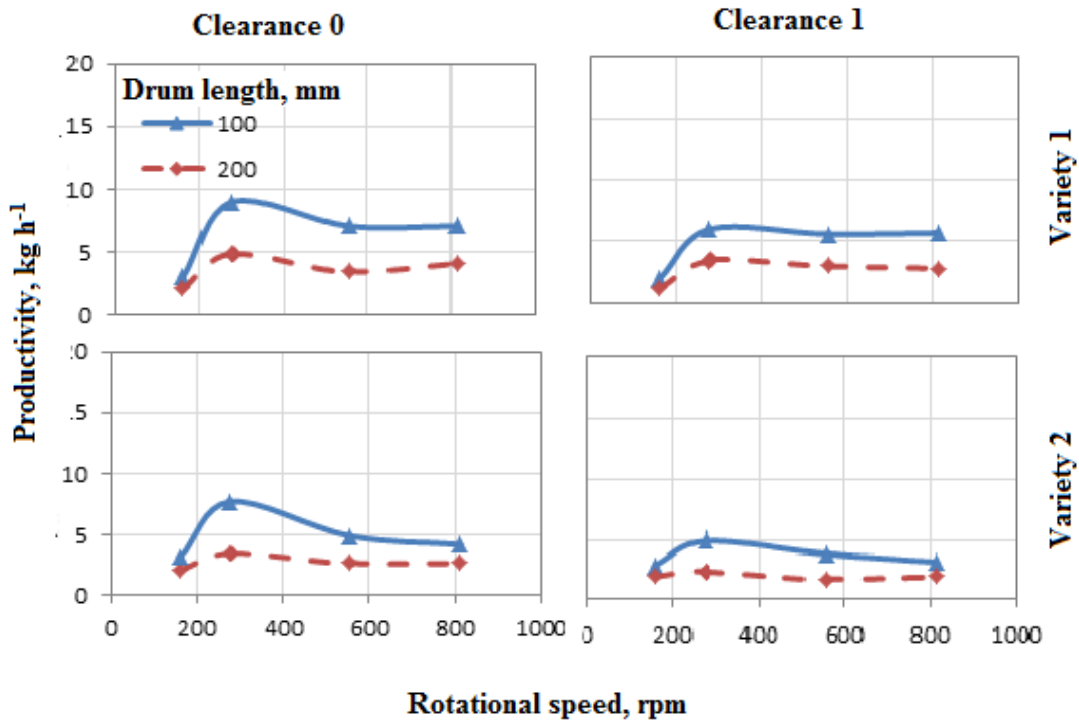
Fig. (7)- The effects of cylinder length, clearance and rotational speed on productivity for variety (1and2) after modification.
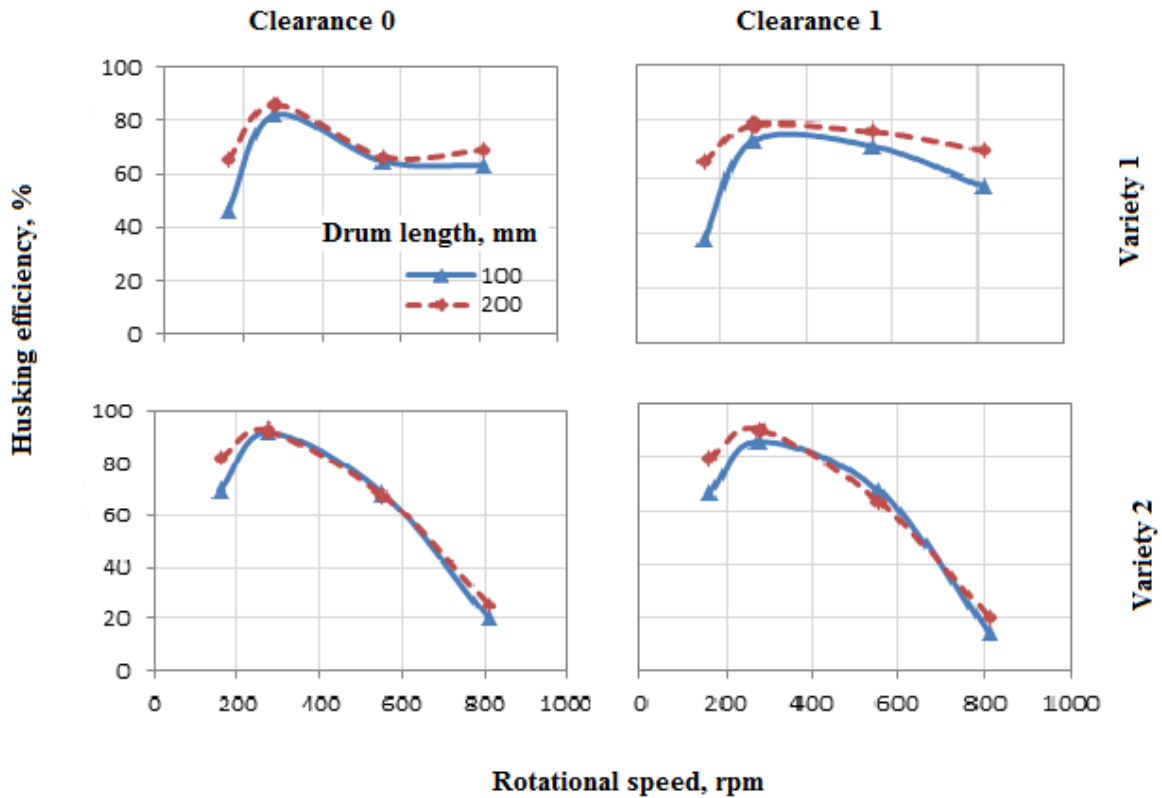

Fig. (8)- The effects of cylinder length, clearance and rotational speed on husking efficiency for variety (1and2) before modification.
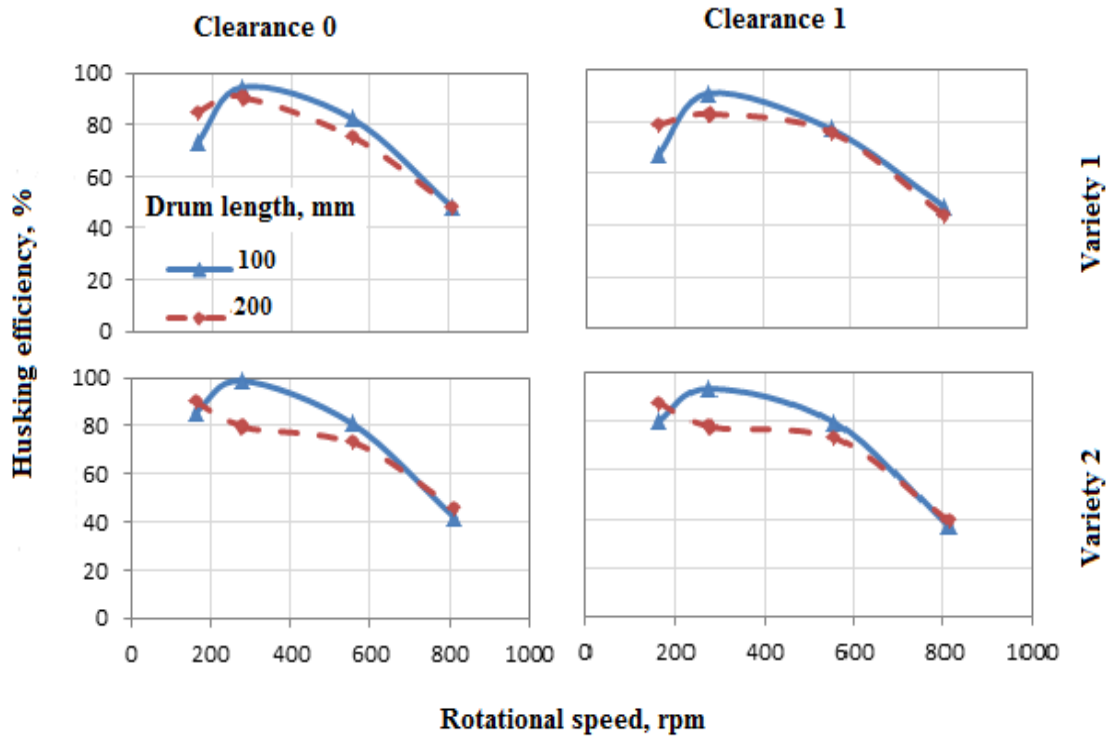
Fig. (9)- The effects of cylinder length, clearance and rotational speed on husking efficiency for variety (1and2) after modification.

3-Consumed energy (CE)
From the table (2) showed that the productivity is inversely proportional to the specific energy where the highest specific energy (for variety 1) was 1.45 kW.h/kg at L_{200}, C_0 and S_{161} ,while the lowest specific energy was 0.09 at L_{100}, C_0 and S_{812} . For variety 2 the highest specific energy was 1.45 kW.h/kg at L_{200}, C_1 and S_{161},while the lowest specific energy was 0.31 at L_{100}, C_0 and S_{277} .From the table (3) showed that the productivity is inversely proportional to the specific energy where the highest specific energy (for variety 1) was 1.37 kW.h/kg at L_{200}, C_1 and S_{161} ,while the lowest specific energy was 0.17 at L_{100}, C_0 and S_{277} . For variety 2 the highest specific energy was 1.00 kW.h/kg at L_{200}, C_1 and S_{555},while the lowest specific energy was 0.21 at L_{100}, C_0 and S_{277} .

4- costs:
According to the suitable conditions for machine, the husking capacity (productivity) were 4.2 and 2.4 kg/h. Also the husking cost was 23.9 L.E / h (this ranged cost of 1.32 to 21.72 L.E/kg) before modification , while the productivity were 9.0 and 7.7 kg/h at cost was ranged of 2.62 to 20.61 L.E/kg after modification. The manual husking capacity and cost are 1.8 kg/h and 11.1 LE/kg, respectively.

In the end, this research recommended manufactured husking machine at combinations of 277 rpm rotational speed of the husking roller, 100 cm the length of the husking cylinder, zero mm clearance distance at feed opening , tilt angle of 144 degree , space between the protrusion of husking cylinder 2.5 cm and the moisture content in corn cobs is about 24 % to optimum performance .

Table (2)- Specific energy with different rotational speed

Husking cylinder		Consumed energy, kW	Productivity, kg/h		Specific Consumed energy, kW.h/kg	
Length, cm	Rotational speed,rpm		Clearance, mm		Clearance, mm	
			0.00	1.0	0.00	1.0
Varity 1 before modification						
100	161	1.6	1.38	1.41	1.16	1.14
	277		6.90	5.32	0.23	0.30
	555		8.11	6.52	0.19	0.24
	812		16.3	11.1	0.09	0.14
200	161		1.13	1.48	1.45	1.08
	277		4.24	3.40	0.34	0.47
	555		4.41	3.70	0.36	0.43
	812		10.72	7.82	0.15	0.21
Varity 2 before modification						
100	161	1.6	1.72	1.51	0.93	1.06
	277		5.23	4.22	0.31	0.38
	555		4.23	3.21	0.38	0.50
	812		2.42	1.61	0.67	1.00
200	161		1.22	1.13	1.31	1.45
	277		2.41	2.41	0.67	0.67
	555		2.32	1.57	0.69	1.02
	812		1.62	1.30	1.00	1.23

Table (3)- Specific energy with different rotational speed

Husking cylinder		Consumed energy, kW	Productivity, kg/h		Specific consumed energy, kW.h/kg	
Length, cm	Rotational speed, rpm		Clearance, mm		Clearance, mm	
			0.00	1.0	0.00	1.0
Varity 1 after modification						
100	161	1.6	2.97	1.97	0.54	0.81
	277		9.04	5.97	0.17	0.27
	555		7.12	5.61	0.23	0.28
	812		7.14	5.70	0.22	0.28
200	161		2.09	1.16	0.77	1.37
	277		4.93	3.44	0.33	0.47
	555		3.52	3.00	0.45	0.53
	812		4.05	2.82	0.39	0.57
Varity 2 after modification						
100	161	1.6	3.11	2.81	0.52	0.57
	277		7.72	4.85	0.21	0.33
	555		4.93	3.80	0.32	0.42
	812		4.20	3.14	0.38	0.52
200	161		2.01	1.84	0.79	0.89
	277		3.41	2.32	0.47	0.69
	555		2.60	1.61	0.62	1.00
	812		2.62	1.79	0.62	0.89

CONCLUSION

The results of the experiments conducted that the highest efficiency of the husking process were 85.9% and 92.2% , for the hybrid and baladi varieties , respectively when using the husking cylinder with a length of 200 cm, rotational speed of 277 rpm and clearance of zero mm. As for consumed energy (electricity) before modification to husk 4 cobs, it was 1.6 kW . Specific consumed energy ranging from 0.9 to 1.23 kW.h / kg and husking time ranging from 15 to 201.3 sec., while the cost was 23.9 L.E / h.

The results of experiments on the machine after modification to husk 4 cobs revealed that the husking efficiency increased to 94.6% and 98.7 % for the hybrid and baladi varieties, respectively, with the use of a peeling cylinder with a length of 100 cm, the rotational speed of 277 rpm, and a clearance of zero mm, while the consumed energy was 1.6 kW. Specific consumed energy ranging from 0.17 to 1.37 kW.h /kg and the husking time ranges from 17 to 203.2 sec., while the cost was 23.9 L.E/h.

The main out comes of the research recommended that in order to obtain the highest husking efficiency, it is preferable to operate the machine under the following conditions;

100 cm length of husking cylinder, 277r.p.m of the husking cylinder, Zero mm clearance distance (without clearance) and 2.5 cm space between the protrusion of husking cylinder.

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تقييم نموذج أولي لآلة مصنعة محلياً لتقشير كيزان الذرة

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[3] أستاذ مساعد بقسم الهندسة الزراعية - جامعة الفيوم – مصر.

الملخص العربي

تعتبر عملية فصل وتنظيف كيزان الذرة من القشور (وغيرها من الشوائب المختلفة) من اهم عمليات ما بعد الحصاد. هذا وتتكون هذه الآلة من الأجزاء التالية: الإطار ـ فتحة التغذية ـ وحدة التقشير – عنصري تغيير السرعة عبارة عن (طارة وسير) - مصدر الطاقة (محرك كهربائي). تم تقييم أداء الماكينة لتحديد الظروف المثلي لتشغيلها من خلال دراسة المتغيرات التالية: استخدام أسطوانتي تقشيرمن الفولاذ بأطوال ١٠٠-٢٠٠ سم، أربع سرعات دورانية لإسطوانة التقشير١٦١-٢٧٧-٥٥٥-٨١٢ لفة في الدقيقة، خلوص بين اسطوانتى التقشير (مطاط وحديد) صفر -١ مم وزاوية ميل ثابنة لفتحة التغذية مقدارها ١٤٤ درجة عند مسافة بين نتوءات أسطوانة التقشير ٥ سم و ٢,٥ سم. وكانت نسبة الرطوبة في الكيزان المستعملة والموصي بها ٢٤ %. ثم دراسة تأثير المتغيرات السابقة علي كل من: زمن التقشير(ثانية)، كفاءة التقشير(%) ،الطاقة المتطلبة (كيلووات) ، الطاقة النوعية (كيلووات. ساعه/كجم) ، التكلفة (جنيه مصري/ساعة) ،الإنتاجية (كجم / ساعة). ولتحسين كفاءة عملية التقشير تم اجراء تعديلات علي هذا النموذج تمثلت في تضييق المسافة بين نتوءات اسطوانة التقشير إلي ٢,٥ سم وزيادة طول إسطوانة التقشير إلي ٢٠٠ سم الذي أدي إلى زيادة الكفاءة والانتاجية. توصلت التجارب إلي أن أعلي كفاءة لعملية التقشير كانت ٨٥,٩ % للصنف الهجين، و٩٢,٩% للصنف البلدي و زادت بمتوسط ٩٤,٦% للصنف الهجين، و ٩٨,٧% للصنف البلدي بعد التعديل، وكانت التكلفة ٢٣,٩ جنيه/ساعه. أوصت الدراسة باستعمال الآلة للحصول علي أعلي كفاءة للتقشير عند استخدام درفيل طوله ١٠٠ سم، سرعة دورانية ٢٧٧ لفة/دقيقة بدون خلوص وعند مسافة ٢,٥ سم بين لفات شريط الحديد الملفوف حلزونيا).
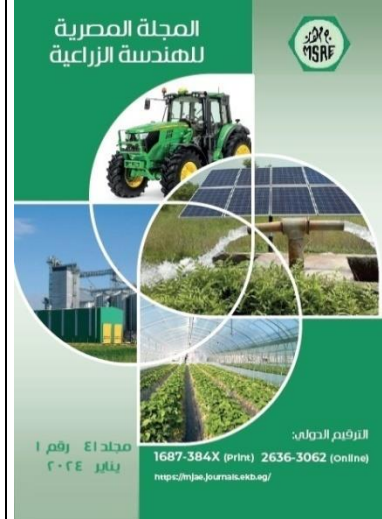
الكلمات المفتاحية:

الذرة الشامية؛ التقشير؛ كيزان الذرة؛ السرعة الدورانية؛ مسافة الخلوص