Journal of Soil Sciences and Agricultural Engineering

Journal homepage: www.jssae.mans.edu.eg
Available online at: www.jssae.journals.ekb.eg

Development of a Simplified Machine for Shelling Maize Grain

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ABSTRACT

Maize shelling is the most important aspect of post-harvest operation of the maize crop. It involves detaching of the maize grain from its cob. The experiments were carried out to develop and construct of a simplified machine for shelling maize grains. The main parts of the developed shelling machine were as follows: feed hopper, shelling chamber, shelling drum, sieved floor, and electrical motor with transmission pulleys and v-belt. The performance of the developed machine was studied under the following parameters:Moisture content of maize grains: 13, 17, 22 %.Drum rotating speeds: 760, 880, and 1080 rpm or (20, 23, 28 m.s-1). Feeding rate: 0.38, 0.40, 0.44 and 0.55 Mg.h-1. The performance of the manufactured machine was evaluated taking into consideration the following indicators: productivity, shelling efficiency, broken ratio, grain losses, energy requirements, operational cost and criterion cost. The experimental results reveal that the highest values of both machine productivity and shelling efficiency were 0.451Mg.h-1 and 90%, respectively. While the lowest values of both specific energy and criterion cost were 3.45kW.h.Mg-1 and 110 L.E.Mg-1, respectively. The optimum operating parameters of the developed shelling machine were found at 880 rpm (23m.s-1) drum speed, 17% grain moisture content and 0.4 Mg.h-1 feed rate.

Keywords: Maize ,Shelling machine , Maize seller, power, criterion cost.

INTRODUCTION

Maize is one of the most important cereal crops in the world. It occupies the second place in terms of production quantity after wheat, and the total global production of cereal crops in 2018 amounted to 2.610 billion Mgs, of which 1.121 billion Mgs of maize, representing 43%. Maize, wheat and rice crops are considered the three main food grain crops, which representing about 92% of the total global production of grain crops. In 2018, the cultivated area of the maize crop globally amounted to 194.6 million hectares, and the average productivity was 5.76 Mg/hectare (17.29 ardebs/feddan). In 2019, the total area planted with maize in Egypt reached about 2,148 feddans (902 thousand hectares) with an average productivity of about 23.15 ardebs/feddan (7.71 Mg/hectare), (Khalifa, 2020). Maize comes after wheat and is accurate in terms of economic importance as maize flour is used in the production of a loaf of bread whether it is alone as it happens in the Egyptian countryside, or by adding it to wheat flour in specific proportions up to about 20% to produce the municipal loaf of bread. Maize is used to feed livestock and poultry and it is used in many other food industries, including maize oil and fructose industries, among others. The amount of corn imports doubled from about 2.5 million tons in 1995 to about 5.52 million tons in 2015 with an estimated value of 8.44 billion pounds, which represents 33% of the value of imports. Central Agency for Public Mobilization and Statistics (2015). Igbinoba *et al.* (2019) presented a dry corn-shelling machine to separate corn from the cob. The fabricated design consists of a body casing, drum, shelling unit, grain and cob discharge unit, machine frame, hopper (Feeding chute), bearing as some of the major component, It is powered by 2 hp electric motor connected via a belt drive which transmits torque from the electric motor to the shelling unit. A blower powered by a separate electric motor connected to the discharge unit helps to separate the unwanted particles from the shelled corn. The fabricated design was tested and found to be about 79 percent efficient with operating capacity of about 63.95 $kg.h^{-1}$. The design is relatively cheap, simple and portable when compared to imported product of similar capacity. Taha *et al.* (2018) stated that increasing the speed of shelling unit led to a higher productivity at the expense of increasing the broken grains. They added that increasing the rotational speed of the shelling unit led to increase the electrical power consumption. Increasing the rotational speed of the shelling unit led to increase the electrical power consumption. El Sharawy *et al.* (2017) indicated that the operating cost decreased by increasing rotational speed and operating cost ranged from 18.19 to 64.42 $EGP.t^{-1}$. The major steps involved in the processing of maize are harvesting, drying, de-husking, shelling, storing, and milling. For the rural farmers to maximize profit from their maize, appropriate technology that suites their needs must be used. The processing of agricultural products like maize into quality forms not only prolongs the useful life of these products, but increases the net profit farmers make from mechanization technologies of such products. One of the most important processing operations done to bring out the quality of maize is threshing or shelling of maize. Shelling process of maize crop is one of postharvest challenges to remove seeds or grains from their respective cobs for both human and industrial use. The difficulty of the shelling process depends on the varieties grown, the moisture

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DOI: 10.21608/jssae.2021.219963

content as well as the degree of maturity of the grain. Traditional shelling methods do not support large-scale shelling of maize, especially for commercial purposes. Hand shelling take a lot of time, even with some hand operated simple tools. The available locally shellers were equipped with rotating shelling drum with beaters or teeth, which cause damages to the maize grains. Besides, the cost of purchasing such shellers were high for the poor rural farmer, and therefore necessitated the design of low-cost machines that will be affordable and also increase shelling efficiency and also reduce damage done to the grains. To achieve the ultimate goal, the following criteria were taken into consideration: Development and manufacturing of a simplified machine locally made for shelling maize grains, determination the most appropriate operating parameters affecting the manufactured shelling machine and evaluation the developed maize shelling machine from the economic point of view.

MATERIALS AND METHODS

This study was carried out through successive agricultural seasons of 2019/2020 to construct and develop a maize shelling machine. This machine was fabricated in a private workshop in Damietta city, Damietta Governorate, Egypt. The samples of maize cobs were bought from the local farmers in Kafr-Saad town, and the main experiments were carried out to evaluate the developed maize sheller in Agricultural Engineering Department, Faculty of Agriculture, (Damietta University. Damietta Governorate. The main experiments were carried out through successive agricultural seasons of 2019/2020 at Agricultural Engineering Department, Faculty of Agriculture, Damietta University to develop, construct and fabricate a locally shelling machine for maize grains. The machine was fabricated in a local workshop in Damietta city, Damietta Governorate, Egypt for shelling maize grains. The samples of maize cobs were bought from the local farmers in Kafr-Saad town, Damietta Governorate.

Materials:

The used crop:

Yellow maize (Giza-370) cobs were used in this study for shelling with the manufactured machine. Some physical properties of maize grains and cobs under this study before shelling operation are shown in Table (1).

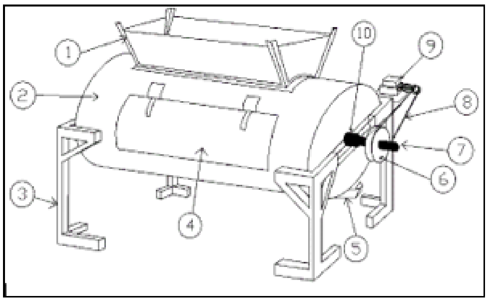
Table 1. Some physical properties of grain maize

Item	Value	Unit
Maize grains:		
AV. Length	11	mm
AV. Width	6.95	mm
AV. Thickness	3	mm
AV. Volume	120	mm^3
Mass of 100 grains	0.025	g
Maize cobs:		
Mean diameter	45	mm
Cob diameter	50	mm
Cob length	220	mm
Geometric mean diameter	8.7	mm
Surface area	55.65	m^2
Maize grains mass on one cob	0.142	g

Developed shelling machine:

The shelling machine was, manufactured, developed and evaluated technically. Fig. (1) show some photos of the developed shelling machine. Fig. (2) show a general 3D drawing of the developed shelling machine.

Fig. 1. Some photos of the developed maize shelling machine.



No.	Part name	No. off	No.	Part name	No. off
1	Hopper	1	6	Pulley	4
2	Shelling drum	1	7	Drum shaft	1
3	Frame	1	8	V- Belt	1
4	Chamber door	1	9	Motor	1
5	Sieve	1	10	Bearing	2

Fig. 2. 3D drawing of the developed shelling maize machine.

(A) Specifications of the developed shelling machine:

The shelling machine used in this study was tested to maximize operating parameters affecting the performance of developed machine and evaluated from an economic point of view. Many considerations were taken during construction the shelling machine as follow:

- Simplicity of the machine components with ease of use by non-specialists.
- Consideration for material selection must be support all stress actions on the machine parts.

- The parts of machine are chosen using locally available materials based on availability, durability and ease for maintenance.
- The materials should be readily available at low cost and sourced locally in all areas of Egypt's governorates.

(B) Construction of the developed shelling machine:

The modifications and the development of the shelling machine were manufactured as follows:

1. Feed hopper: The feed hopper was manufactured form trapezoid mild steel shape**.** The dimensions of the feed hopper were 80 cm in length, 78cm in width of the upper base, 30cm in width of the lower base and 38cm in the height. This hopper used for feeding the machine with maize cobs. The inlet gate is equipped with a slide metal sheet to open and close the shelling chamber during shelling action.

2. Shelling chamber: The maize shelling chamber consists of three main parts as following**:**

♦ **Shelling cylinder:** The shelling cylinder made from steel sheet 2mm thickness with total length of 96cm and 58cm in diameter. This cylinder was welded to the general frame and contains the shelling drum. This cylinder was welded also with the feed hopper from the upper side to receive the maize cobs, and acting as a concave with 12mm hole diameter from the lower side.

♦ **Drum shaft:** A central shaft is located longitudinally inside the cylinder; it is made of a steel pipe of 3cm designed outer diameter. The length of shaft was 96 cm, which has pegs/chains located at 12cm in equally spaced in eight rows. Each chain was 25cm long that rotate along the cylinder. These chains do the shelling action of maize whereby the cobs are being impact with those metallic chains and then the seeds are extracted and fall afterwards into a sieved floor through the perforated concave.

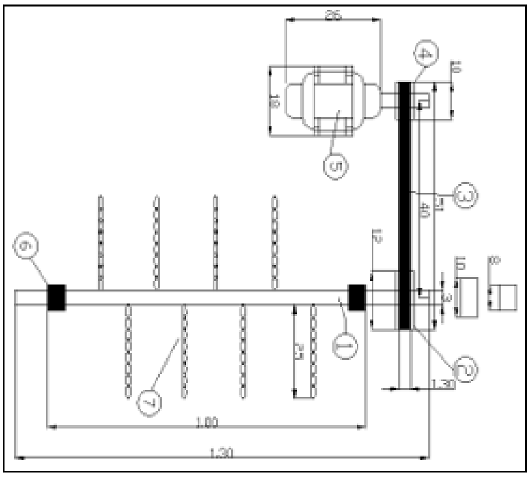
♦ **Shelling chamber door:**

The shelling chamber door dimension was (28×70) cm, as shown in Fig. (2). This door used to close the shelling chamber tightly during shelling process to prevent the maize grains to come out of the shelling chamber, and to allow the maize cobs to throw out from the shelling chamber after separating maize grains from the cobs.

3. Sieved floor: The sieved floor was located under the perforated concave of the shelling cylinder. The sieved floor was trapezoidal in shape and has dimensions of 10cm in width from the lower side, 85cm width from the upper side and 90cm in length. The inclination angle of the sieved floor was 30° to allow the maize grains glide fast toward the outlet gate. The holes diameter of the sieved floor was 10mm to purify the maize grains from any impurities.

4. The main frame: The main frame of maize shelling machine made from steel. It includes elements to fix the electric motor, the shelling chamber with its components, the power transmission system. The dimensions of the frame base were (112×76) cm, length and width. It was fixed to the ground using four arms with total height of 102 cm.

5. Power transmission: An electrical motor of 1.10kW (1.5hp) at maximum rated speed of 880 rpm powered the maize shelling machine. The electrical motor transmits its rotating motion through a pulley with 10cm in diameter and v-belt to the shelling shaft at three different pulley diameters of (8, 10 and 12 cm) to change the rotating speed of the shelling shaft under the experimental conditions, as shown as in Fig. (3).



No.	Part name	No. off
1	Drum shaft	1
2	Machine pulley	3
3	V – Belt	1
4	Motor pulley	1
5	Electric motor	1
6	Bearing	2
7	Pegs/Chains	8

Fig. 3. Power transmission from electrical motor to shelling shaft.

(C) Design of shelling shaft considerations:

The shelling shaft is supported by two bearings. The first bearing locating beside the shelling changeable pulleys, and the second bearing locating at the end of the shaft behind the shelling chamber. There are two loads affecting the shelling shaft. The first load (F_1) was transported from the weight of drum pulley, tension on the tight side of v-belt and tension on the slack side. The second load (F_2) was due to maximum hopper weight with maize cobs and drum chains weight. These two loads are in to different planes and directions, as shown in Fig. (4). The shelling shaft under these loads is subjected to both torsion and bending stresses. The diameter of the shelling shaft can be calculated according to the maximum shear theory, according to Khurmi and Gupta, (2005).

$$\tau_{max} = \frac{1}{2}\sqrt{\delta^2 + 4\,\tau^2} \;\ldots\ldots\ldots\ldots(1)$$

$$\tau_{max} = \frac{16}{\pi\, d^3}\sqrt{K_m^{\,2}.Mb^2 + K_t^{\,2}.T^2}\;,\quad kg/cm^2 \ldots\ldots\ldots\ldots(2)$$

$$\tau_{max} = \frac{16}{\pi\, d_o^{\,3}(1-k^4)}\sqrt{K_m^{\,2}.Mb^2 + K_t^{\,2}.T^2}\;,\quad kg/cm^2 \ldots\ldots\ldots\ldots(3)$$

Where:

τ_{max} = Maximum shear stress = 450 kg.cm^{-2}
δ = Bending stress, kg.cm-^{2}
τ = Shear stress, kg.cm-^{2}
Mb = Maximum bending moment, kg.cm
T = Maximum torque kg.cm
d = Diameter of shelling shaft, cm
k = Ratio of inside diameter and outside diameter of the shaft = 80%
K_m = Shock factor for bending = 2
K_t = Shock factor for torsion = 2

1. Determination of maximum torque (T_{max}):

The maximum torque at the shelling shaft can be calculated from the motor horsepower and rotating speed as follows:

$$T_{max} = \frac{71640HP}{N} = \frac{71640 \times 1.5}{700} = 153.5 \cong 155 kg.cm \quad ....(4)$$

Where:

HP = Motor power = 1.5hp.

N = Minimum rotating speed for shelling shaft = 700rpm.

2. Determination of maximum bending moment (M_{max}):

Maximum bending moment can be calculated from (F_1 and F_2) acting on the hollow shaft.

3. Determination of (F_1):

F_1 = Maximum weight of grains in the hopper and drum shaft and chains weight = 40 + 4.5 = 44.5kg

4. Determination of (F_2):

$$F_2 = T_1 + T_2 + W \quad ....(5)$$

Where:

F_2 = Tension force on pulley, kg ,

T_1 = Tension on the tight side of belt, kg

T_2 = Tension on the slack side of belt, kg ,

W = Weight of pulley, kg

$$T_m = 155 \ kg.cm^{-2} \quad ....(5)$$

$$T_m = (T_1 - T_2).r \quad \therefore \quad (T_1 - T_2) = \frac{155}{6} = 26 \quad ....(6)$$

Where:

T_m = Torque at pulley shaft, kg.cm

r = pulley radius = 6cm

$$\text{Ratio of tensions on the belt} = 2.3\log\left(\frac{T_1}{T_2}\right) = \mu\,\theta\cos\alpha \quad ....(7)$$

Where:

μ = Coefficient of friction, 0.3,

θ = Angle of contact, rad ,

α = Groove angle of pulley, 40°

$$\theta = [(180 - (2\ \alpha)]\pi/180 \quad .... (8)$$

$$\therefore \quad \theta = [(180 - (2 \times 40)]3.14 / 180 = 1.74 \ rad$$

$$\therefore 2.3\log\left(\frac{T_1}{T_2}\right) = 0.3 \times 1.74 \times \cos 40° \quad ....(9)$$

$$\frac{T_1}{T_2} = e^{2.3 \times 0.422} \quad \therefore \frac{T_1}{T_2} = 2.64 \quad \& \quad T_1 = 2.64\,T_2 \quad ....(10)$$

From equation (6) and (10), we get the follows:

$$\therefore T_1 = 41.85\,kg \quad \& \quad T_2 = 15.85\,kg$$

$$\therefore F_1 = 15.85 + 41.85 + 3 = F_1 = 60.7 \approx 61kg \quad ....(11)$$

5. Determination of (F_2V) at vertical direction:

$$F_2V = (T_1 + T_2)\sin 11° - W \quad ....(12)$$

$$\therefore F_2V = 9.92 - 3 = 6.92\,kg$$

6. Determination of (F_2H) at horizontal direction:

$$F_2H = (T_1 + T_2)\cos 11°$$

$$\therefore F_2H = 56.84 \ kg \quad ....(13)$$

7. Determination vertical reactions:

By using the loading diagram Fig. (4), the reactions on bearing shaft (R_A) and (R_B) with vertical direction can be calculated as following:

$$\sum M \, at \, B = 0 \quad ....(14)$$

$$\therefore (R_A \times 100) = (6.92 \times 5) + (44.5 \times 50)$$

$$100R_A = 2259.6 \quad \therefore \quad R_A = 22.6 \approx 23kg$$

$$\& \sum Y = 0 \quad ....(15)$$

$$\therefore R_A + R_B + 6.92 = 44.5 \quad \therefore \quad R_B = 14.98 \approx 15kg$$

8. Determination horizontal reactions:

By using the loading diagram Fig. (4), the reactions on bearing shaft (R_A) and (R_B) with horizontal direction can be calculated as following:

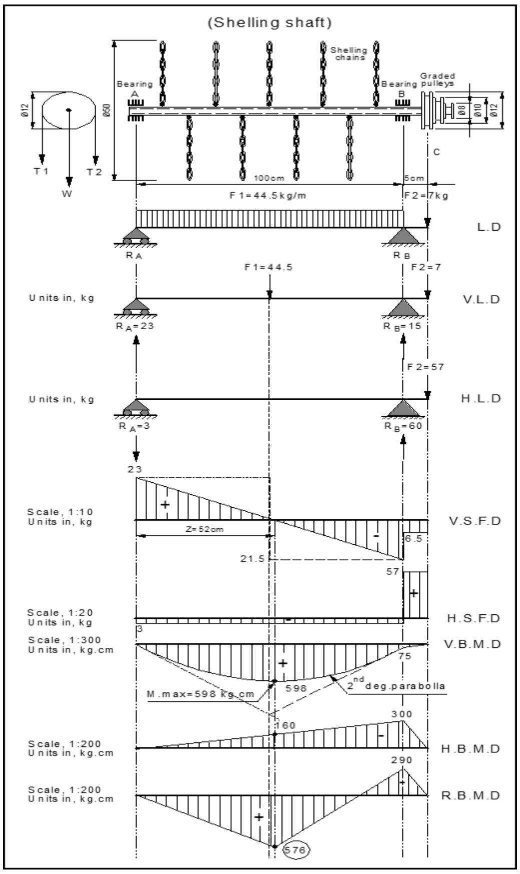


Fig. 4. Stress analysis on shelling shaft.

$$\sum M \, at \, B = 0 \quad ....(16)$$

$$\therefore (R_A \times 100) + (56.84 \times 5) = 0$$

$$100R_A = -284.2 \quad \therefore \quad R_A = -2.84 \approx -3kg$$

$$\& \sum Y = 0 \quad ....(17)$$

$$\therefore R_A + 56.84 = R_B \quad \therefore \quad R_B = 59.84 \approx 60kg$$

9. Determination the vertical moments:

$$M_A = 0.0kg.cm$$

$$M_B = (23 \times 100) - (44.5 \times 50) = 75kg.cm$$

$$M_C = 0kg.cm$$

$$M_D = 23 \times 50 = 1150 \ kg.cm$$

10. Determine the horizontal moments:

$$M_A = 0.0kg.cm$$

$$M_B = -3 \times 100 = -300kg.cm$$

$$M_C = 0kg.cm$$

11. Determination the resultant moments:

$$M_A = 0.0kg.cm$$

$$M_B = \sqrt{(75)^2 - (300)^2} = -290kg.cm$$

$$M_C = 0kg.cm$$

$$M_{M.max} = \sqrt{(598)^2 - (160)^2} = 576 \ kg.cm \quad ....(18)$$

So, from Fig. (4) the maximum resultant moment on the shelling shaft, M_{max}= (576 kg.cm). Then the maximum shear theory is applied as follows:

$$Z_{max} = \frac{16}{\pi d_o^3(1-k^4)}\sqrt{K_m^2\,(Mb)^2 + K_t^2\,T^2} \quad \therefore 450 = \frac{16}{1.85\,d_o^3}\sqrt{2^2 \times (576)^2 + 2^2 \times (155)^2}$$

$$\therefore 450 = \frac{16}{1.85\,d_o^3} \times 1193 \quad \therefore d_o^3 = 22.93 \quad \therefore d_o = 2.84\,cm = 28.4mm$$

$$(\text{So, take } d_o = 30mm \quad \& \quad d_i = 24mm) \quad ....(19)$$

Methods:

The main experiments were carried out to develop, manufacture and evaluate the performance of the maize shelling machine.

Experimental conditions:

Preliminary experiments were carried out to determine the most affected parameters on the developed maize shelling machine. The performance of the developed machine was experimentally measured under the following parameters:

- Three moisture contents of maize grains of 13, 17 and 22% (w.b).
- Three drum rotating speeds of 760, 880, and 1080 rpm (20, 23, 28 $m.s^{-1}$).
- Four hopper feeding rate of 0.38, 0.40, 0.44 and 0.55 $Mg.h^{-1}$.

Measurements and determinations:

Evaluation of maize shelling machine was performed taking into consideration the following indicators**:**

1. Physical properties of maize grains and cobs:

A random sample of one hundred maize grains was taken from yellow maize variety to measure the length (L), width (W), thickness (T). The obtained data were studied in arithmetic mean diameter (D_a), geometric mean diameter (D_g), Spherecity (ø), surface area (S), moisture content of grains (M_C), and mean hundred-grains mass and that is using the digital balance.

$$V = \frac{\pi}{6}(L.W.T), \text{ mm}^3 \text{……..……...(20)}$$

$$D_g = 3\sqrt{L.W.T}, \text{ mm…..……......(21)}$$

$$\varphi = \frac{\sqrt[3]{(L.W.T)}}{3}, (\%) \text{…….........(22)}$$

$$S = \frac{3\sqrt{L.W.T}}{L} \times 100, \% \text{ ……..……..(23)}$$

$$D_a = \frac{(L + W + T)}{3}, \text{ mm……….........(24)}$$

$$M_C = \frac{(M_W - M_d)}{M_W} \times 100 \text{ …………...(25)}$$

Where:

L = mean length of maize grain, (mm)
W = mean width of maize grain, (mm)
T = mean thickness, (mm)
Da = arithmetic mean diameter of maize grain, (mm)
Dg = geometric mean diameter of maize grain, (mm)
V = mean volume of maize grain, (mm)
ø = mean seed sphericity, (%)
S = surface area, (mm2)
Mc = moisture content of grains, (%)
Ww = sample mass before drying, (g)
Wd = mass after drying sample, (g)

2. Machine productivity:

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

$$MP = \frac{Wp}{T} \text{ ………………….. (26)}$$

Where: **MP: Machine productivity, $Mg.h^{-1}$. , Wp: Maize grains mass, g. , T: Operating time, h.**

3. Shelling efficiency:

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

$$SE = (1 – Ung) \times 100 \text{ …….(27)}$$

Where: **SE = Shelling efficiency of the modified machine, %. ,**
Ung = Unshelled grains on cobs, kg.

4. Unshelled grains:

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

$$UNg = M_2 / (M1 + M_2) \times 100 \text{……….(28)}$$

Where: **UNg = Unshelled grain on cobs, kg. ,**
M_1 = Mass of shelled grains, kg., M_2 = Mass of unshelled grains, kg.

5. Grain damage (Mechanically broken grains):

It was determined after a random sample of 100g was weighed out of each treatment. Afterwards, the broken grains were isolated by suitable sieves according to the following formula given by Naveenkumar (2011):

$$Gd = Md / Mt \times 100 \text{ ………… (29)}$$

Where:

Gd = grain damaged, %. , Md = Mass of damaged grains, g. , Mt = Mass of total grains in the sample, g.

6. Grain losses:

The grain losses which found with the residual of cobs were weighted and then its percentage was calculated as follows:

$$L.g = \frac{Mk}{Mt} \times 100 \text{ …………..….(30)}$$

Where:

L.g = Grain losses, %. , Mt = Mass of grains from outlet, %. , Mk = Mass of grains on cobs, kg.

7. Power required:

Power required was determined by using a clamp meter to gauge the electrical current change during conducting the treatment process, the consumed power was determined according to (Ashby, 1982):

$$P = \sqrt{3} \cos\theta \times I \times V \times \frac{1}{1000} \text{……… (31)}$$

Where:

P = Required power, (kW). , I = Current intensity, (A), V = Voltage, (380V), $\cos\theta$ = Constant, (0.7).

8. Energy consumed:

The following formula was used to obtain the energy consumed:

$$ER = \frac{P}{EP} \text{……………..… (32)}$$

Where:

ER = Energy consumed, ($kW.h.Mg^{-1}$) , P: Required power, (kW) , EP = Machine productivity, ($Mg.h^{-1}$).

9. Operational cost:

The operational cost was estimated using the following equation:

$$Co = \frac{Ec}{EP} \text{ ….…………..(33)}$$

Where:

Co = Operational cost, ($L.E.Mg^{-1}$)
MC = Machine hourly cost, ($L.E.h^{-1}$)

The machine hourly cost was determined using the following equation, (Awady, 1978):

$$MC = \frac{P}{h}\left(\frac{1}{a} + \frac{i}{2} + t + r\right) + (W \times e) + \frac{m}{192} \text{ ………………..(34)}$$

Where:

MC = Machine cost, ($L.E.h^{-1}$)
P = Machine price, (L.E)
h = Yearly working hours, ($h.year^{-1}$)
a = Life expectation of the machine, (h)
i = Interest, ($rate.year^{-1}$)

t = Taxes, over heads ratio
r = Repairs and maintenance ratio
W = Required power, (kW)
e = Electricity cost, (L.E.kW^{-1})
m = The monthly worker wage, (L.E)
192 = Reasonable estimation of monthly working hours.

10. Criterion cost:

Criterion cost can be determined using the following equation:

[Criterion cost, (L.E.Fed^{-1}) = Operational cost+losses cost]…(35)

RESULTS AND DISCUSSION

The main results obtained are summarized under the following points:

Effect of some operating parameters on machine productivity:

Results in Fig. (5) show the effect of feeding rate on machine productivity. Increasing feed rate from 0.38 to 0.55 Mg.h^{-1} lead to increase machine productivity values during shelling maize grains from 0.300 to 0.410, from 0.305 to 0.451 and from 0.304 to 0.425 Mg.h^{-1} under different drum rotating speeds of 760, 880 and 1080 rpm and constant grain moisture content of about 17%. These results were due to increase the feeding rate of the non-separated cobs increased. The increased weights of the feed rate of the machine caused an incomplete connection between the threshing chains and the corn. Increasing time makes the amount of shelled seeds increased too so the productivity increased.

Concerning to the effect of grain moisture content on machine productivity, results in Fig. (5) show that increasing grain moisture content from 13 to 17 % lead to increase machine productivity values during shelling maize grains from 0.287 to 0.305, from 0.316 to 0.333, from 0.347 to 0.364 and from 0.440 to 0.451 Mg.h^{-1} under different feed rates of 0.38, 0.40, 0.44 and 0.55 Mg.h^{-1} and constant drum rotating speeds of 880 rpm. While, increasing grain moisture content from 17 to 22 % lead to decrease the machine productivity from 0.305 to 0.292, from 0.333 to 0.320, from 0.364 to 0.349 and from 0.451 to 0.440 Mg.h^{-1}, at the same previous conditions. This result was due to the low pressure on the grain in the threshing chamber increase machine production. Decreasing of sheller productivity with increasing of grain moisture content was due to the fragility of the maize grains and adhesion in the cobs.

As to the effect of drum rotating speed on machine productivity, Results in Fig. (5) show that increasing drum rotating speed from 760 to 880 rpm lead to increase machine productivity values during shelling maize grains 0.300 to 0.305, from 0.320 to 0.333, from 0.340 to 0.364 and from 0.410 to 0.451 Mg.h^{-1}. Under different feed rates of 0.38, 0.40, 0.44 and 0.55 Mg.h^{-1} and constant grain moisture content of about 17%. While, increasing drum rotating speed from 880 rpm to 1080 rpm lead to decrease the machine productivity from 0.305 to 0.304, from 0.333 to 0.327, from 0.364 to 0.359 and from 0.451 to 0.425 Mg.h^{-1}. These results was due to the speed of 880 rpm did not have any unshelled granules that were suitable for the diameter of the shelling cylinder and the amount of corn entering the cylinder while the speed of 1080 rpm has exceeded the appropriate limit that is not commensurate with the size of the bombing mechanism and the bombing mechanism.

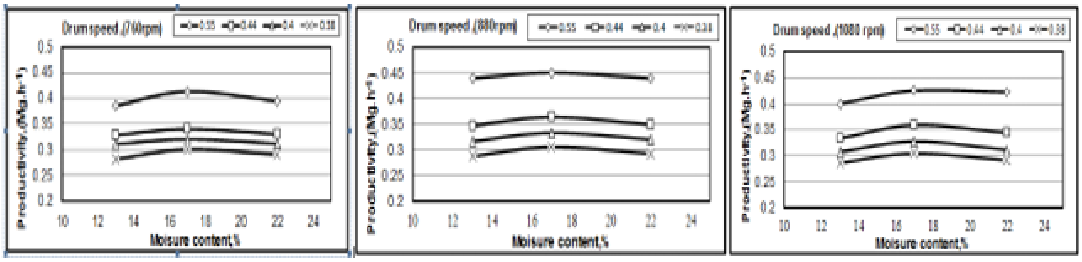


Fig. 5. Some operating parameters affecting on machine productivity.

Effect of some operating parameters on shelling efficiency:

Results in Fig. (6) show the effect of feeding rate on shelling efficiency. Increasing feed rate from 0.38 to 0.4 Mg.h^{-1} lead to increase shelling efficiency values during shelling maize grains from 85 to 87, from 89 to 90 and from 88 to 89 % under different drum rotating speeds of 760, 880 and 1080 rpm and constant grain moisture content of about 17%. While increasing feed rate from 0.4 to 0.55 Mg.h^{-1} lead to decrease shelling efficiency values during shelling maize grains from 87to 82, from 90 to 87 and from 89 to 85 %, at the same previous conditions. These results were due to increasing the feeding rate of the non-separated cobs increased. The increased weights of the feed rate of the machine caused an incomplete connection between the threshing chains and the corn. Increasing the feeding rate caused a decrease in the shelling efficiency as a result of the increase in the unshelled grain that comes with the increase in feeding weight.

Concerning to the effect of grain moisture content on shelling efficiency, results in Fig. (6) show that increasing feed rate from 0.38 to 0.4 Mg.h^{-1} lead to increase the moisture content from 13 to 17 % lead to decrease shelling efficiency values during shelling maize grains from 82 to 89, from 83 to 90, from 80 to 88 and from 74 to 87 % under different feed rates of 0.38, 0.40, 0.44 and 0.55 Mg.h^{-1} and constant drum rotating speeds of 880 rpm. While, increasing grain moisture content from 17 to 22 % lead to increase the shelling efficiency from 89 to 85, from 90 to 87, from 88 to 85 and from 87 to 80 %, at the same previous conditions. This result was due to the operation requiring a relatively high rate of energy expenditure and the extracted kernels tend to have suffered considerable damage during the process.

As to the effect of drum rotating speed on shelling efficiency, results in Fig. (6) show that increasing the drum rotating speed from 760 to 880 rpm lead to increase shelling efficiency values during shelling maize grains 85 to 89, from 87 to 90, from 83 to 88 and from 82 to 87 %. Under different feed rates of 0.38, 0.40, 0.44 and 0.55 Mg.h^{-1} and constant grain moisture content of about 17%. While, increasing drum rotating speed from 880 rpm to 1080 rpm lead to decrease the shelling efficiency from 89 to 88, from 90 to 89, from 88 to 84 and from 87 to 85 %, at the same previous condition. These results was due to the speed of 880 rpm did not have any unshelled granules that were suitable for the diameter of the shelling cylinder and the amount of corn entering the cylinder while the speed of 1080 rpm has exceeded the appropriate limit that is not commensurate with the size of the bombing mechanism and the bombing mechanism. The decrease breakage percentage by decreasing the rotational speed hence increased shelling efficiency.

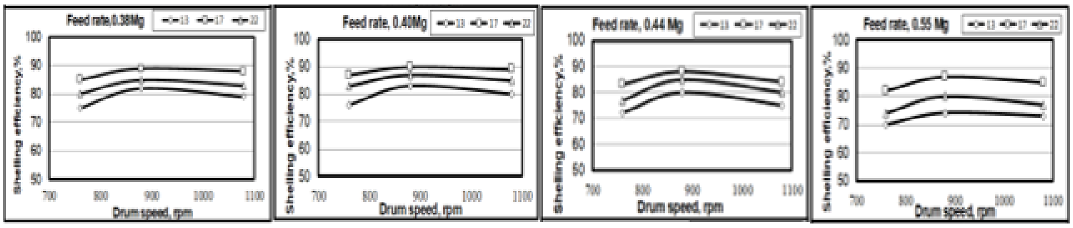


Fig. 6. Some operating parameters affecting on shelling efficiency.

Effect of some operating parameters on grain losses:

Results in Fig. (7) show the effect of feeding rate on grain losses. Increasing feed rate from 0.38 to 0.4 $Mg.h^{-1}$ lead to decrease grain losses values during shelling maize grains from 3.66 to 2.8, from 2.7 to 1.7 and from 2.8 to 1.9%, under different drum rotating speeds of 760, 880 and 1080 rpm and constant grain moisture content of about 17%. While increasing feed rate from 0.4 to 0.55 $Mg.h^{-1}$ lead to increase grain losses values during shelling maize grains from 2.8 to 4, from 1.7 to 3.1 and from 1.9 to 3.2%, at the same previous conditions. These results were due to the feed rate is high on the cobs, their number is large, the number of shocks is few on the cobs, so there are unshelled grains. The increased weights cause an incomplete connection between the threshing chains and the cobs.

Concerning to the effect of grain moisture content on grain losses, results in Fig. (7) show that increasing the moisture content from 13 to 17% lead to decrease grain losses values during shelling maize grains from 3 to 2.7, from 2.3 to 1.7, from 2.7 to 2.2 and from 3.4 to 3.1 %, under different feed rates of 0.38, 0.40, 0.44 and 0.55 $Mg.h^{-1}$ and constant drum rotating speeds of 880 rpm. While, increasing grain moisture content from 17 to 22% lead to increase grain losses from 2.7 to 4.33, from 1.7 to 3.5, from 2.2 to 3.9 and from 3.2 to 4.7%, at the same previous conditions. These results were due to with the increase moisture content, the adherence of the corn kernels to the cobs increases with the slow speed, which is difficult to shell.

As to the effect of drum rotating speed on grain losses, results in Fig. (7) show that increasing the drum rotating speed from 760 to 880 rpm lead to decrease grain losses values during shelling maize grains from 3.66 to 2.7, from 2.8 to 1.7, from 3.2 to 2.2 and from 4 to 3.1%, under different feed rates of 0.38, 0.40, 0.44 and 0.55 $Mg.h^{-1}$ and constant grain moisture content of about 17%. While, increasing drum rotating speed from 880 rpm to 1080 rpm lead to increase the grain losses from 2.7 to 2.8, from 1.7 to 1.9, from 2.2 to 2.3 and from 3.1 to 3.2%, at the same previous conditions. These results were due to increase the speed, the number of shocks on the cobs increases, which leads to their shelling.

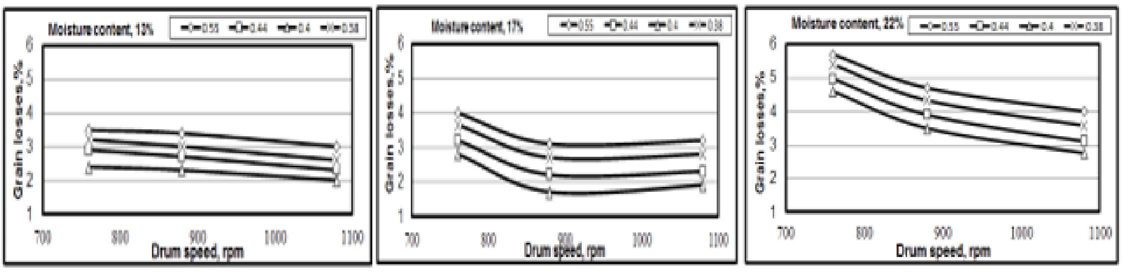


Fig. 7. Some operating parameters affecting on grain losses.

Effect of some operating parameters on energy requirements:

Results in Fig. (8) show the effect of feeding rate on energy requirements. Increasing feed rate from 0.38 to 0.55 $Mg.h^{-1}$ lead to decrease energy requirements values during shelling maize grains from 3.83 to 2.80, from 3.77 to 2.55 and from 3.78 to 2.71 $kW.h.Mg^{-1}$, under different drum rotating speeds of 760, 880 and 1080 rpm and constant grain moisture content of about 17%. These results were due to increase in the maize kernels weight that enters the threshing cylinder resulted in more power consumption by the rotating shaft to overcome this weight.

Concerning to the effect of grain moisture content on energy requirements, results in Fig. (8) show that increasing the moisture content from 13 to 17% lead to decrease energy requirements values during shelling maize grains from 4 to 3.77, from 3.63 to 3.45, from 3.15 to 3.14 and from 2.61 to 2.55 $kW.h.Mg^{-1}$, under different feed rates of 0.38, 0.40, 0.44 and 0.55 $Mg.h^{-1}$ and constant drum rotating speeds of 880 rpm. While, increasing grain moisture content from 17 to 22 % lead to increase energy requirements from 3.77 to 3.94, from 3.45 to 3.59, from 3.14 to 3.29 and from 2.55 to 2.61%, at the same previous conditions. This result was due to increased Damocles effort on grains during the threshing process hence increased capacity consumed with increasing corn grains moisture content. As increasing the grain moisture leads to increase of the power consumption, at different grain moisture contents. This is due to the increased damocles effort on grains during the shelling process.

As to the effect of drum rotating speed on energy requirements, results in Fig. (8) show that increasing the drum rotating speed from 760 to 880 rpm lead to decrease energy requirements values during shelling maize grains from 3.83 to 3.77, from 3.62 to 3.45, from 3.38to 3.14 and from 2.80 to 2.55 kW.h.Mg^{-1}, under different feed rates of 0.38, 0.40, 0.44 and 0.55 Mg.h^{-1} and constant grain moisture content of about 17%. While, increasing drum rotating speed from 880 rpm to 1080 rpm lead to increase the energy requirements from 3.77 to 3.78, from 3.45 to 3.52, from 3.14 to 3.20 and from 2.55 to 2.71 kW.h.Mg^{-1}, at the same previous conditions. These results were due to increase in the drum of speed, the energy consumed increased due to the increase in the engine load, with the increase in the speed of the rotating shaft, which the chains require more energy from the engine to rotate the shaft.

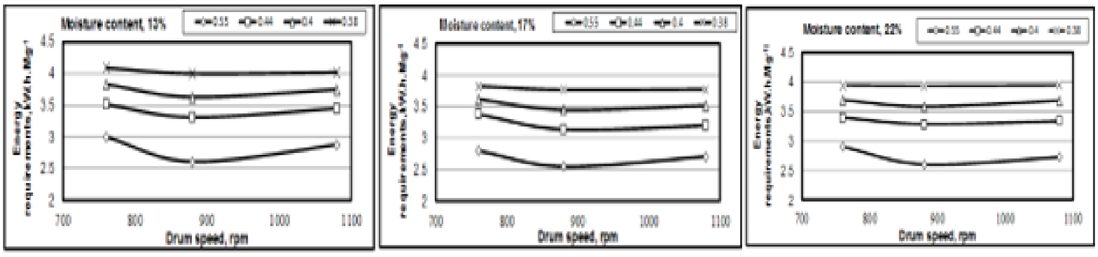


Fig. 8. Some operating parameters affecting on energy requirements.

Effect of some operating parameters on operating cost:

Results in Fig. (9) show the effect of feeding rate on operating cost. Increasing feed rate from 0.38 to 0.55 Mg.h^{-1} lead to decrease operating cost values during shelling maize grains from 83 to 61, from 82 to 55 and from 82 to 59 L.E.Mg^{-1}, under different drum rotating speeds of 760, 880 and 1080 rpm and constant grain moisture content of about 17%.

Concerning to the effect of grain moisture content on operating cost, results in Fig. (9) show that increasing the moisture content from 13 to 17% lead to decrease operating cost values during shelling maize grains from 87 to 81, from 79 to 75, from 72 to 67 and from 57 to 55 L.E.Mg^{-1}, under different feed rates of 0.38, 0.40, 0.44 and 0.55 Mg.h^{-1} and constant drum rotating speeds of 880 rpm. While, increasing grain moisture content from 17 to 22 % lead to increase operating cost from 81 to 85, from 75 to 78, from 67to 72 and from 55 to 57 L.E.Mg^{-1}, at the same previous conditions.

As to the effect of drum rotating speed on operating cost, results in Fig. (9) show that increasing the drum rotating speed from 760 to 880 rpm lead to decrease operating cost values during shelling maize grains from 83 to 81, from 78 to 75, from 74 to 67 and from 61 to 55 L.E.Mg^{-1}, under different feed rates of 0.38, 0.40, 0.44 and 0.55 Mg.h^{-1} and constant grain moisture content of about 17%. While, increasing drum rotating speed from 880 rpm to 1080 rpm lead to increase the operating cost from 81 to 82, from 75 to 76, from 67 to 70 and from 55 to 59 L.E.Mg^{-1}, at the same previous conditions.

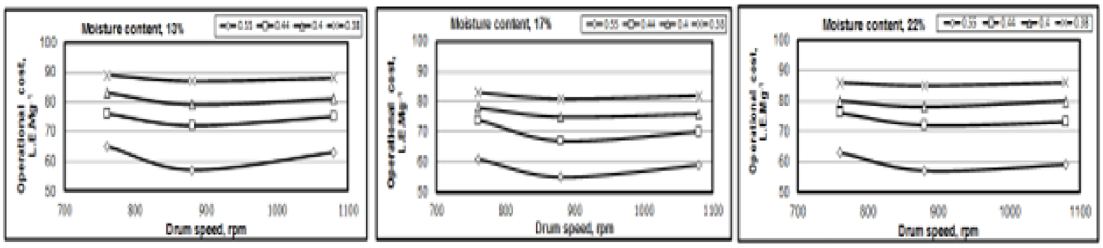


Fig. 9. Some operating parameters affecting on operational cost.

Effect of some operating parameters on criterion cost:

Results in Fig. (10) show the effect of feeding rate on criterion cost. Increasing feed rate from 0.38 to 0.4 Mg.h^{-1} lead to decrease criterion cost values during shelling maize grains from 153 to 134, from 132 to 110 and from 133 to 115 L.E.Mg^{-1}, under different drum rotating speeds of 760, 880 and 1080 rpm and constant grain moisture content of about 17%.While increasing feed rate from 0.4 to 0.55 Mg.h^{-1} lead to increase criterion cost values during shelling maize grains from 134 to 164, from 110 to 143 and from 115 to 142 L.E.Mg^{-1}, at the same previous conditions.

Concerning to the effect of grain moisture content on criterion cost, results in Fig. (10) show that increasing the moisture content from 13 to 17 % lead to decrease criterion cost values during shelling maize grains from 144 to 132, from 125 to 110, from 134 to 120 and from 152 to 143 L.E.Mg^{-1}, under different feed rates of 0.38, 0.40, 0.44 and 0.55 Mg.h^{-1} and constant drum rotating speeds of 880 rpm. While, increasing grain moisture content from 17 to 22 % lead to increase criterion cost from 132 to 167, from 110 to 148, from 120 to 157 and from 143 to 180 L.E.Mg^{-1}, at the same previous conditions.

As to the effect of drum rotating speed on criterion cost, results in Fig.(10) show that increasing the drum rotating speed from 760 to 880 rpm lead to decrease criterion cost values during shelling maize grains from 153 to 132, from 134 to 110, from 143 to 120 and from 164 to 143 L.E.Mg^{-1}, under different feed rates of 0.38, 0.40, 0.44 and 0.55Mg.h^{-1} and constant grain moisture content of about 17%. While, increasing drum rotating speed from 880 rpm to 1080 rpm lead to increase the criterion cost from 132 to 133, from 110 to 115, from 120 to 123 and from 143 to 142 L.E.Mg^{-1}, at the same previous conditions.

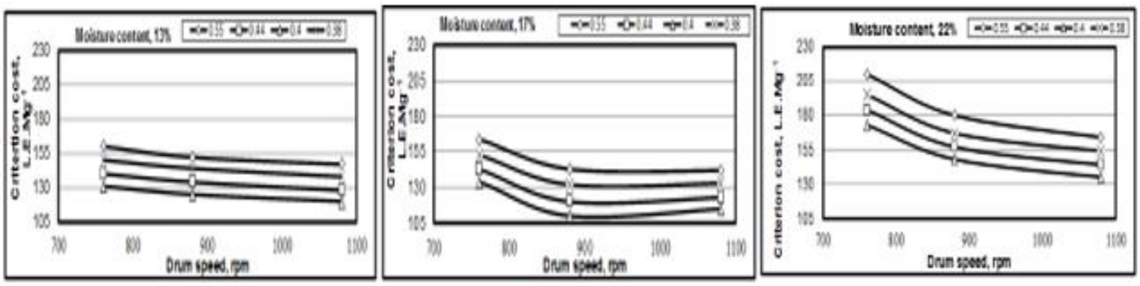


Fig. 10. Some operating parameters affecting criterion cost.

CONCLUSION

The main experiments were carried out through successive agricultural seasons of 2019/2020 at Agricultural Engineering Department, Faculty of Agriculture, Damietta University to develop, construct and fabricate a locally shelling machine for maize grains. The machine was fabricated in a local workshop in Damietta city, Damietta Governorate, Egypt for shelling maize grains. The samples of maize cobs were bought from the local farmers in Kafr-Saad town, Damietta Governorate.

The objectives of this study are to:

- Development and manufacturing of a simplified machine locally made for shelling maize grains.
- Determination the most appropriate operating parameters affecting the manufactured shelling machine.
- Evaluation the developed shelling machine from the economic point of view.

The developed maize selling machine consists of the feed hopper, shelling chamber, sieved floor, power transmission and the main frame. The developed shelling machine was evaluated under three deferent parameters of maize moisture content, drum rotating speeds and Hopper feeding rates.

The experimental results reveal that the highest values of both machine productivity and shelling efficiency were 0.451Mg.h-1 and 90%, respectively. While the lowest values of both specific energy and criterion cost were 3.45kW.h.Mg-1 and 110 L.E.Mg-1, respectively. The optimum operating parameters of the developed shelling machine were found at 880 rpm (23m.s-1) drum speed, 17% grain moisture content and 0.4 Mg.h-1 feed rate.

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تطويـر آلــة مبسطــة لتفريــط حبــوب الــذرة

مُحب محمد أنيس الشرباصي ومنة الله محمود المالح

قسم الهندسة الزراعية - كلية الزراعة - جامعة دمياط.

تعتبر الذرة من أهم محاصيل الحبوب في العالم حيث تحتل المرتبة الثانية من حيث كمية الإنتاج بعد القمح. كما أن لها دوركبيربعد القمح والأرز في غذاء الإنسان. تستخدم الذرة أيضاً كعلف لتغذية الماشية والدواجن، كما تستخدم في العديد من الصناعات الغذائية الأخرى مثل صناعة زيت الذرة والفركتوز وغيرها. تعد عملية تفريط الذرة أو فصل الحبوب عن الكيزان من أهم عمليات مابعد الحصاد. وتعتبر هذه العملية أحد أهم تحديات ما بعد الحصاد للحصول على الحبوب النظيفة بطريقة سهلة لتهيئتها لعمليات التصنيع اللاحقة. تم تصنيع الآلة المطورة في ورشة خاصة بمدينة دمياط وتم إجراء التجارب العملية لتقييم هذه الآلة في قسم الهندسة الزراعية، كلية الزراعة، جامعة دمياط في الموسم الصيفي ٢٠٢٠م. أجريت التجارب الرئيسية على آلة تفريط الذرة محلية الصنع لتحديد عوامل التشغيل المناسبة التي من خلالها يتم الحصول على أعلى إنتاج بتكاليف تشغيل مناسبة وأقل طاقة مستهلكة، وتحددت أهداف الدراسة الرئيسية فيما يلي: تطوير آلة محلية الصنع لتفريط الذرة. اختبار أنسب عوامل التشغيل التي تؤثر على أداء الآلة تفريط الذرة المصنعة. تقييم آلة تفريط الذرة المطورة والمصنعة محلياً من الناحية الاقتصادية. تم تقييم آلة تفريط الذرة محلية الصنع بأخذ عوامل التشغيل التالية: سرعة الدرفيل الفصل: ٧٦٠ ، ٨٨٠ و ١٠٨٠ لفة/دقيقة . محتوى رطوبي للحبوب: ١٣ ، ١٧ و ٢٢ ٪. معدل تغذية: ٠,٣٨ ، ٠,٤٠ ، ٠,٤٤ و ٠,٥٥ ميجاجم/ساعة. تم تقييم أداء الآلة المطورة والمصنعة محلياً من خلال القياسات التالية: الإنتاجية، كفاءة الفصل، نسبة فواقد الحبوب الكلية، استهلاك الطاقة، تكاليف التشغيل، التكاليف الحدية. أظهرت النتائج التجريبية أن أعلى قيم لكل من إنتاجية الماكينة وكفاءة التفريط كانت ٠,٤٥١ ميجا جم/ الساعة و ٩٠٪ على التوالي. بينما كانت أدنى قيم لكل من استهلاك الطاقة والتكلفة الحدية ٣,٤٥ كيلووات. ساعة / ميجاجم و ١١٠ جنيهاً/ ميجاجم على التوالي. تم العثور على معاملات التشغيل المثلى لآلة الفصل (التفريط) المطورة عند ٨٨٠ دورة في الدقيقة (٢٣ م.ث/ثانية) سرعة الأسطوانة ، ١٧٪ محتوى رطوبي للحبوب و ٠,٤ ميجا جم/ الساعة معدل تغذية.