Manufacturing and Performance Evaluation of a Local Machine for Grinding Maize Grains

El-Sharabasy, M. M. A. and Hanady S. S. Soliman[*]

Agric., Eng., Dept., Faculty of Agriculture, Damietta Univ., Egypt

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ABSTRACT

The experiments were carried out to develop and construct a local grinding machine for grinding yellow maize grains for producing animal fodder. The performance of the developed machine was studied under the following parameters: Four different drum speeds of (1400, 1600, 1900 and 2300rpm) or (26, 30, 36 and 43m/s) , three screen hole diameters of (3.5, 5, and 8.5mm) and three different patch sizes of (5, 10, and 15kg). The performance of the manufactured machine was evaluated taking into consideration the following indicators: machine productivity, particle size distribution (fineness degree, medium degree, coarse degree), required power, specific energy and operational cost. The experimental results reveal that the highest value of machine productivity was 931kg/h, while the lowest values of both specific energy and operational cost were 3.1kW.h/Mg, and 21.8L.E./Mg, respectively. The optimum operating parameters of the developed grinding machine were obtained at 1900 rpm (36m/s) drum speed by using 8.5mm screen diameter with patch size of about 15kg.

Keywords: grinding, maize, machine, productivity, energy, fineness degree

INTRODUCTION

Maize is a summer crop that is used as human food, animal feed, an important source of the oil industry, low water consumption, low costs, and suitable for cultivation in most agricultural lands in Egypt. Corn in large quantities solves most of the nutritional problems that Egypt suffers from. Maize, or Zeamays L, is the world's third most important seed–yield, coming in third place behind Wheat and Rice in terms of planted area and production. Yellow Maize enters percentage of 50-70% of the poultry feed because of its low fiber and high-fat content in comparison with other forage grains makes it highly digestible to feed poultry and is considered one of the richest grains with thermal energy and contains a high percentage of vitamin A. Maize production helps to lower feed prices by accounting for 70% of plant feed components, while leaves and stems are utilized as green fodder.

Its total area in the world in the year 2019 was 487,302 million feddans with a total production of 1,148 billion Mg, (FAO, 2019). Its total area in Egypt in the year 2019 was 2.458 million feddans with a total production of 7,450 million Mg, (FAO, 2019). Pérez-Bonilla *et al.* (2014); Dabbour *et al.* (2015); Herrera *et al.* (2018) referred to that maize is eaten directly by humans, animal feed, uniformly nutritive poultry diets, corn starch, corn syrup, oil, protein, and as a co-product as anthocyanins, which are used as naturally sourced colors in food and cosmetics, alcoholic drinks, and more recently as bio-fuels. Ali *et al.* (2019) mentioned that, a) Using chains instead of traditional hammers had a noticeable impact on the grinder indicators and ground particle measurements. b) Chains had a major impact on

all the studied indicators when the sieves' diameter was increased from 4 to 6 and then to 8 mm. c) Chain hammers with an 8mm sieve diameter used the least amount of energy, had the highest power, and caused the least temperature increase. Abd Elmotalb and Bejo (2009) found that as the hammer rotating speed increased from 20.1 to 44.2 m/s at any screen hole diameter, the system efficiency and power demand of the grinding process increased.

As the screen hole diameter decreased from 7 to 2 mm, the milled product's fineness improved. Ahmed *et al.* (2006) studied that sieve openings and grain form are two important factors that influence machine ability and energy consumption. The use of sieves with small openings results in an improvement in the fineness of the ground substances, which before getting out of the sieves openings and the capacity decreases in turn alternatively more electricity is needed to rotate inside the internal grinder case.

The diameters of the used sieve openings had an effect on the average of the measured ground-particle values. Kumar and Vettivel (2014) stated that grinding demands a large amount of energy for each volume of particles, which leads to an increase in the temperature of the grinding zone as a result of the force applied and friction.

The problem in producing these devices is to retain excellent quality while increasing production and reduce costs.

This paper reports on the development and testing of a local grinding machine for grinding maize grains to feed the animals which increasing both processing industries in Egypt and animal resource. So, such care had to be taken to develop and operate the machine under

the optimum conditions to minimize both specific energy and operational cost. Thus, the objectives of this research are to:

1. Develop and manufacture local grinding machines to be suitable for grinding the maize grains.
2. Optimize some operating parameters (drum speed, screen diameter, and Patch size) affecting the performance of the developed machine.
3. Evaluate the developed machine from an economic standpoint.

MATERIALS AND METHODS

This study was carried out through the year 2020 in El-Westany town, Damietta Governorate to develop and construct a locally grinding machine for grinding the yellow maize grains. The sample of maize grain was bought from the local farmers in El-Westany town, Damietta Governorate.

Materials

The used crop

Yellow maize (HYTECH 110 variety) having a moisture content of 8.6 % (wet basis) was used in this study. Some physical properties of the used maize variety under this study before grinding operation are shown in Table (1).

Table 1. Some physical properties of grain maize (variety of HYTECH-110 variety).

Item	Value	Unit
AV. Length	12.64	mm
AV. Width	9.07	mm
AV. Thickness	4.38	mm
AV. Volume	263.19	mm^3
Mass of 100 grains	37	g
Arithmetic Mean diameter	8.7	mm
Geometric mean diameter	7.95	mm
Spherecity	2.65	%
Surface area	198.51	mm^2
Moisture content of grains	8.6	%
Angle of repose	28	degree
Static coefficient of friction	53	degree

Developed machine

The grinding machine was, manufactured, developed and evaluated technically.

Fig. (1) shows a general 3D drawing of the developed grinding machine.

Specifications of the developed grinding machine

The developed grinding machine used in this study was manufactured, developed, and tested at a workshop in El-Westany town, Damietta Governorate, Egypt.

Many considerations were taken during constructed the grinding machine as follow:

1. Construction and Simplicity by locally available materials.
2. Develope and manufacture local grinding machine to be suitable for grinding maize grains.
3. Consideration for material selection was based on availability, durability, ease of machining, and cost.
4. Evaluate the machine from an economic standpoint.

Construction of the developed grinding machine

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

a) Feed hopper

The hopper was designed and manufactured with hopper gate. The hopper made from steel iron having two openings, one of which is at the top to receive maize grains for grinding with dimensions of (72×72×26cm) for length, width, and height, respectively. The sides of this hopper sloped gradually to allow sliding of maize grains and keep continuous flow at an adequate feed rate from the hopper to the grinding chamber. Therefore, there is another slope at the bottom of the hopper to feed the maize grains into the grinding chamber with dimensions of (17×12cm) for length and width.

The hopper bottom has a slope angle of (32 degrees) on the horizontal level. The feed hopper is not welding with the mainframe of the machine, but it was fixed with four steel bolts. The machine's feeding process is manually controlled to control the throat width through a sliding gate fixed at the hopper bottom to control grain falling from the hopper based on product free fall with dimensions of (23×13cm) for length and width, gate thickness of 2mm.

b) Grinding chamber

The grinding maize machine having three main parts as follows:

● **Grinding drum**

The grinding drum is a horizontal steel shaft with 2.5cm in diameter and 39.2cm in length laid on two horizontal bearings and supported with two steel flanges having a diameter of 17cm and thickness of 4mm, each flange was bored at its outer circumference to receive two steel bars with total length of 10cm. Each bar loaded with 4 equal hammers each one having dimensions of (160×30×6 mm). The grinding drum has 8 hammers with 1.5cm between each one on the same bar.

● **The lower part: (serves as the concave)**

The lower part of the grinding chamber is a screen made of steel with dimensions of (110×17× 0.2cm) for length, width, and thickness. The clearance between hammers and machine concave was 15mm. The maize grains are disintegrated because of the action of the hammers. Pass through the screen holes at the desired diameter of grinding.

● **The upper part**

The upper half of the grinding chamber is a smooth semicircle with an opening for dropping the maize into the grinding chamber.
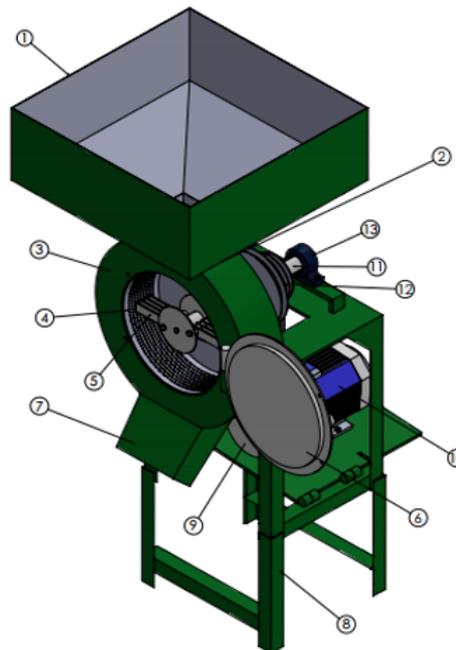
● **Grinding chamber door**

There is a door to close the grinding chamber tightly so that no yellow maize grains come out, and this door is closed with a screw. The grinding chamber door diameter is 40 cm.

c) Power transmission

The machine was powered by an electric motor of 2.91kW (3hp) at the maximum rated speed of 1400 rpm. The electric motor transmits its rotating motion to the grinding shaft by means of pulley with 15cm in diameter and V-belt powered to changeable pulleys on the grinding shaft to obtain the experimented drum rotating speeds, as shown in Fig. (2).

No.	Part name	No. off
1	Feed hopper	1
2	Gate	1
3	Grinding chamber	1
4	Screen	3
5	Hammer	8
6	Grinding chamber door	1
7	Out let	1
8	Machine frame	1
9	Motor pulley	4
10	Electric motor	1
11	Drum shaft	1
12	Machine pulley	4
13	Bearing	2

Fig.1. 3D drawing of the developed grinding machine.

No.	Part name	No. off
1	Hammer	8
2	Drum shaft	1
3	Bearing	2
4	Machine pulley	4
5	Motor pulley	4
6	Electric motor	1
7	V-Belt	2
8	Grinding chamber	1

All dimensions, mm
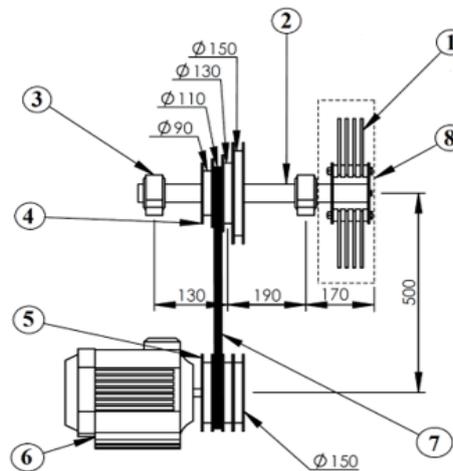
Fig. 2. Power transmission from electric motor to grinding shaft.

d) The main frame

The main frame of grinding machine is constructed from steel. It includes elements to fix the electric motor, the grinding chamber, and its components, the power transmission system. It is fixed to the ground by four arms with a total height of 98cm and width of 53cm.

(E) Design of grinding shaft:

The transported power shaft is supported by two bearings. The first bearing locating in the case which includes the pulling gears, and the second bearing locating at the end of the shaft behind the grinding chamber. There are two loads affecting the transported power shaft. The first load (F₁) was transported from the weight of pulley, Tension on the tight side of belt and Tension on the slack side of belt. Second distributed load (F₂) due to Maximum hopper mass and drum knives mass added to the sample mass. These two loads are in the same plane and direction, as shown in Fig. (3). The shaft under these loads is subjected to combined bending and torsion stresses. The diameter of the transported power shaft can be calculated according to the maximum shear theory as following:

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

$$\tau_{max} = \frac{1}{2}\sqrt{\left\{\frac{32\,M}{\pi\,d^3}\right\}^2 + 4\left\{\frac{16\,T}{\pi\,d^3}\right\}^2} \,\ldots\ldots\ldots(2)$$

$$\tau_{max} = \frac{16}{\pi\,d^3}\sqrt{K_m^{\,2}\,M^2 + K_t^{\,2}\,T^2} \,\ldots\ldots\ldots(3)$$

Where:

τ_{max} = Maximum shear stress, τ_{max} = 450 kg/cm2

σ = astress, kg/cm²
M = Maximum bending moment, kg.cm
T = Maximum torque kg.cm
d = Diameter of ashaft, cm
Km= Shock factor for bending, 2
Kt = Shock factor for tension, 1.5

● **Determination of maximum torque, (T$_{max}$):**

The maximum torque at the transported power shaft can be calculated as follows:

$$T_{max} = F_{max} \times r, \ kg.cm \ldots\ldots\ldots\ldots(4)$$

Where:

T_{max} = Maximum torque at grinding power shaft, kg. cm
F_{max} = Maximum force at grinding shaft, kg
r = Radius of grinding drum, cm

The maximum force required for pulling plants along the pulling bar can be calculated as follows:

$$T_{max} = \frac{71640 \times 3}{1400} = 153.5 \cong 155 kg.cm$$

$$\therefore F_{max} = \frac{155}{7.5} = 21 kg$$

● **Determination of maximum bending moment, (M_{max}):**
Maximum bending moment can be calculated from (F_1, F_2) as follows:

1. Determination of F_1:

$$F_1 = T_1 + T_2 + W \ldots\ldots\ldots\ldots (5)$$

Where:

F_1 = Tension force on pulley, kg   &   W = Weight of pulley, kg
T_1 = Tension on the tight side of belt, kg   & T_2 = Tension on the slack side of belt, kg

$$\because T_m = 21 \times 7.5 = 157.5 \ kg.cm \quad \therefore (T_1 - T_2) = 21 kg.cm$$

$$\therefore (T_1 - T_2) = \frac{157.5}{7.5} \quad \& \quad T_m = (T_1 - T_2) \times r$$

Where:

T_m= Torque at pulley shaft, kg.cm   r = Radius of power shaft pulley, cm
F_{max} = Maximum tension force at power shaft, kg

$$\because \text{Ratio of tensions} = \frac{T_1}{T_2} = e^{\mu e \theta} \quad \& \quad \mu e = \frac{\mu}{\sin \beta} \ldots\ldots(6)$$

Where:

μ = Coefficient of friction, 0.3
β = Groove angle of pulley, $73°$

$$\therefore \mu e = \frac{0.3}{0.478} \qquad \therefore \qquad \mu e = 0.63$$

$$\because \theta = \pi - 2 \sin^{-1}\left[(D_2 - D_1)/2C\right] \ldots\ldots\ldots(7)$$

Where:

θ = Angle of contact, rad
D_1 = Diameter of power shaft pulley, 15cm.
D_2 = Diameter of conveyor belt pulley, 15cm.
C = Distance between the two axis of pulleys, 50cm

$$\therefore \theta = 3.14 - 2\sin^{-1}\left[(15-15)/2 \times 50\right] = 3.14 \ rad$$

$$\therefore \frac{T_1}{T_2} = e^{0.63 \times 3.14} \qquad \therefore \frac{T_1}{T_2} = \ldots\ldots(8)$$

From equation (5) and (7) we get the follows:

$$\therefore T_2 = 3.37 kg \qquad \& \because T_1 = 7.23 T_2 \qquad \therefore T_1 = 24.37 kg$$

$$\therefore F_1 = 24.37 + 3.37 + 3.75 \qquad\qquad \therefore F_1 = 31.5 kg$$

2. Determination of F_2:

F_2 = Maximum weight of grains in the hopper and drum knives weight = 50 + 4.5 = 54.5kg

3. Determination of (R_A and R_B):

$$\because \sum M \ at \ B = 0 \ \ldots\ldots\ldots\ldots(9)$$

$$\therefore (R_A \times 32) + (54.5 \times 8.5) = (31.5 \times 19)$$

$$32 R_A = 598.5 - 463.25 \quad \therefore R_A = 4.22 \approx 4 kg$$

$$\& \because \sum Y = 0 \ \ldots\ldots\ldots\ldots(10)$$

$$\therefore R_A + R_B = 31.5 + 54.5 \quad \therefore R_B = 82 kg$$

By using the loading diagram. The reactions on bearing shaft (R_A) and (R_B) can be calculated as follows:

$$M_A = 0.0 kg.cm$$

$$M_C = (4 \times 13) = 52 kg.cm$$

$$M_B = (4 \times 32) - (31.5 \times 19) = -470 kg.cm$$

$$M_D = 0.0 kg.cm$$

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

From stress analysis on grinding shaft shown in Fig (3) and safty factors taken for bending stress and torsion stress of 2 and 1.5, respectively, the maximum bending moment on the grinding shaft equal Mmax= (470 kg.cm). Then the maximum shear theory is applied as follows:

$$\tau_{max} = \frac{16}{\pi d^3}\sqrt{K_m^2 \ M^2 + K_t^2 \ T^2}$$

$$\therefore 450 = \frac{16}{3.14 d^3}\sqrt{2^2 \times (470)^2 + 1.5^2 \times (154)^2}$$

$$\therefore 450 = \frac{16}{3.14 d^3} \times 989.17 \quad \therefore d^3 = 11.20 \quad \therefore d = 2.24 cm$$

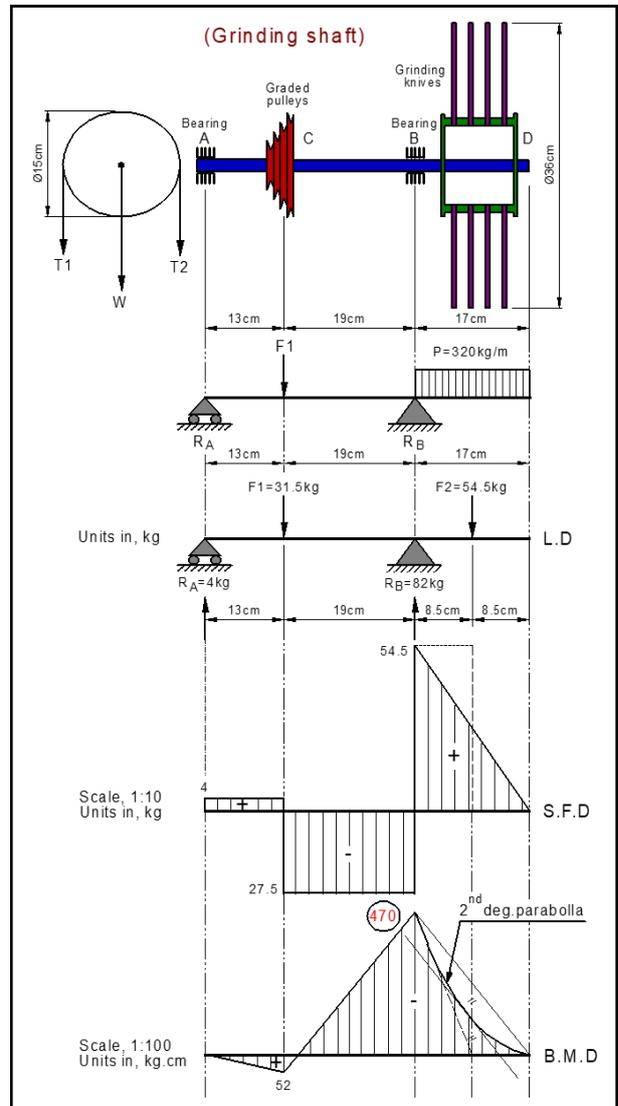(So, the grindig shaft was taken 25mm)

Fig. 3. Stress analysis on grinding shaft.

Methods:

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

Experimental conditions

Preliminary experiments were carried out to develop local maize grinding machine. The performance of the developed machine was experimentally measured under the following parameters:

1- Four different drum speeds of (1400, 1600, 1900 and 2300rpm) or (26, 30, 36, 43m/s).

2- Three screen hole diameters of (3.5, 5, and 8.5mm).

3- Three different patch sizes of (5, 10, and 15kg).

Measurements and Determinations

Evaluation of grinding machine was performed taking into consideration the following indicators:

Determination of the crop's physical properties

A random sample of one hundred maize grains was taken from (HYTECH 110) 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. hundred-grains mass and that is using the digital balance.

$$V = \frac{\pi}{6}(L.W.T), mm^3 \quad\ldots\ldots\ldots\ldots(11)$$

$$D_g = 3\sqrt{L.W.T}, mm \quad\ldots\ldots\ldots\ldots(12)$$

$$\varphi = \frac{\sqrt[3]{(L.W.T)}}{3}, (\%) \quad\ldots\ldots\ldots\ldots(13)$$

$$S = \frac{3\sqrt{L.W.T}}{L} \times 100, \% \quad\ldots\ldots\ldots\ldots(14)$$

$$D_a = \frac{(L+W+T)}{3}, mm \quad\ldots\ldots\ldots\ldots(15)$$

$$M_C = \frac{(M_W - M_d)}{M_W} \times 100 \quad\ldots\ldots\ldots\ldots(16)$$

Where:
L = mean length of maize grain, (mm)
W = mean width of maize grain, (mm)
T = mean thickness, (mm)
D_a = arithmetic mean diameter of maize grain, (mm)
D_g = geometric mean diameter of maize grain, (mm)
V = mean volume of maize grain, (mm)
ø = mean seed sphericity, (%)
S = surface area, (mm²)
M_c = moisture content of grains, (%)
W_w = sample mass before drying, (g)
W_d = mass after drying sample, (g)

Determination of the crop's mechanical properties

Angle of repose

The angle of repose is the angle at which the material would stand when stacked in relation to the horizontal. A rectangular box filled with grains was held horizontal to measure the angle of repose. After that, the grains were allowed to fall onto a horizontal circular disc that was held below the box. After the grains were completely heaped on the disc, the flow of grains was halted. The height and radius of the heap's base were determined, and the angle of repose

was estimated using the following formula (Sahay and Singh, 1994).

$$\theta = \tan^{-1}\left(\frac{h_o}{r}\right) \quad\ldots\ldots\ldots(17)$$

Where:
θ = angle of repose, (degree)
h_o = height of heap, (m)
r = radius of heap, (m)

Static coefficient of friction

The static coefficient of friction of maize samples against MS sheet surface were determined. The coefficient of friction was calculated from the following equation: (Tarighi *et al.*, 2011).

$$\mu = \tan\theta \quad\ldots\ldots\ldots\ldots(18)$$

Where:
μ = static coefficient of friction
tanθ= angle of repose, degree

Machine productivity:

The machine productivity was calculated during grinding operation by the following equation:

$$M_P = \frac{M_S}{t} \quad\ldots\ldots\ldots\ldots(19)$$

Where:
M_p = machine productivity, Mg/h,
M_s = mass of milled maize sample, Mg,
t = time consumed in the grinding operation, h

Fineness degree (Particle size distribution):

The ground maize samples were classified into three main categories according to Henderson and Hansen (1968). The first one is fine milled maize FMC (< 3mm), the second is medium milled maize MMC (3-4.2 mm) and the third is coarse milled maize CMC (> 4.2mm).

Required power:

The following formula was used to estimate the required power (Ashby, 1988).

$$Po = \sqrt{3} \times \cos\varphi \times I \times V \quad\ldots(20)$$

Where:
Po = power required, kW
I = current intensity, Ampere
V = Voltage, (380 V)
cosφ = 0.92

Specific energy:

$$SE = \frac{Po}{Mp} \quad\ldots\ldots(21)$$

Where:
SE = Specific energy consumption, kW.h/Mg
Po = power required, kW
M_p = machine productivity, Mg/h

Operational cost:

The operational cost required for the grinding operation was estimated using the following equation: (Awady, *et al.* 1982).

$$C_{op.} = \frac{C}{Mp} \quad\ldots\ldots\ldots(22)$$

Where:
$C_{op.}$ = operational cost, L.E/Mg
M_p = machine productivity, Mg/h
C = hourly cost, L.E/h

The hourly cost of grinding operation was determined using the following equation: (Awady, 1978).

$$C = \frac{p}{h}\left(\frac{1}{a} + \frac{i}{2} + t + r\right) + (W.e) + \frac{m}{144} \quad \text{......(23)}$$

Where:

C = hourly cost, L.E/h
h = yearly working hours, h/year
i = interest rate/year
t = taxes, over heads ratio
r = repairs and maintenance ratio
P = price of machine, L.E
a = life expectancy of the machine, y
W = motor power, hp
e = hourly kW price, L.E/kW.h
m = monthly average wage, L.E
144 = reasonable estimation of monthly working hours

RESULTS AND DISCUSSION

The obtained results will be discussed under the following items:

Influence of drum speed on machine productivity at different patch sizes and different screen diameters.

Relating to the effect of drum speed on machine productivity is given in Fig. (4A). Results show that at screen diameter of 3.5mm, increasing drum speed from 1400 to 1900 rpm measured at different patch sizes of about 5, 10 and 15kg increased machine productivity from 240 to 327.3, from 300 to 375, and from 350.6 to 432kg/h, respectively. Any further increase in drum speed more than1900 up to 2300 rpm measured at the same patch sizes decreased machine productivity from 327.3 to 310.3, from 375 to 356.4 and from 432 to 412.2kg/h, respectively. The machine productivity increased by increasing grinding drum speed, the reason is that the period of time for the exit of grinding maize grains is shorter when the patch sizes increase from 5 to 15kg.

Relating to the effect of drum speed on machine productivity is given in Fig. (4B). Results show that at screen diameter of 5mm, increasing drum speed from 1400 to 1900rpm measured at different patch sizes of about 5, 10 and 15kg increased machine productivity from 600 to 692.3, from 654.5 to 734.7, and from 692.3 to 771.4kg/h, respectively. Any further increase in drum speed more than1900 up to 2300rpm measured at the same patch sizes decreased machine productivity from 692.3 to 666.7, from 734.7 to 705.8 and from 771.4 to 750kg/h, respectively. The machine productivity increased by increasing grinding drum speed, the reason is that the period of time for the exit of grinding maize grains is shorter when the patch sizes increase from 5 to 15kg.

Relating to the effect of drum speed on machine productivity is given in Fig. (4C). Results show that at screen diameter of 8.5mm, increasing drum speed from 1400 to 1900 rpm measured at different patch sizes of about 5, 10 and 15kg increased machine productivity from 750 to 857.1, from 800 to 900, and from 857.1 to 931kg/h, respectively.

Any further increase in drum speed more than 1900 up to 2300 rpm measured at the same patch sizes decreased machine productivity from 857.1 to 818.2, from 900 to 878 and from 931 to 915.3kg/h, respectively. The machine productivity increased by increasing grinding drum speed, the reason is that the period of time for the exit of grinding maize grains is shorter when the patch sizes increase from 5 to 15kg.
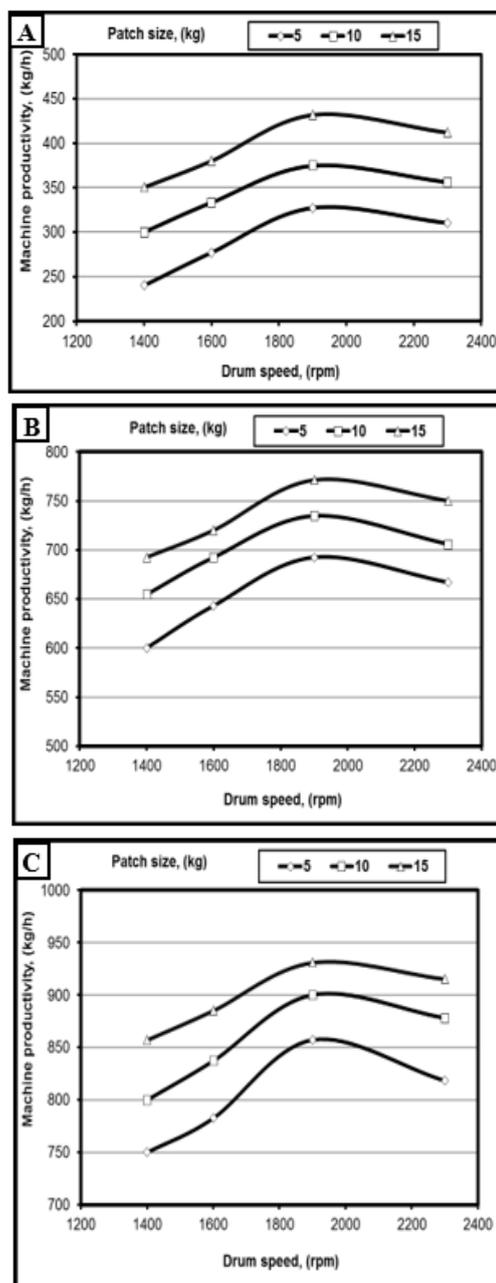

Fig. 4. Effect of drum speed on machine productivity at different patch sizes and different screen diameters.
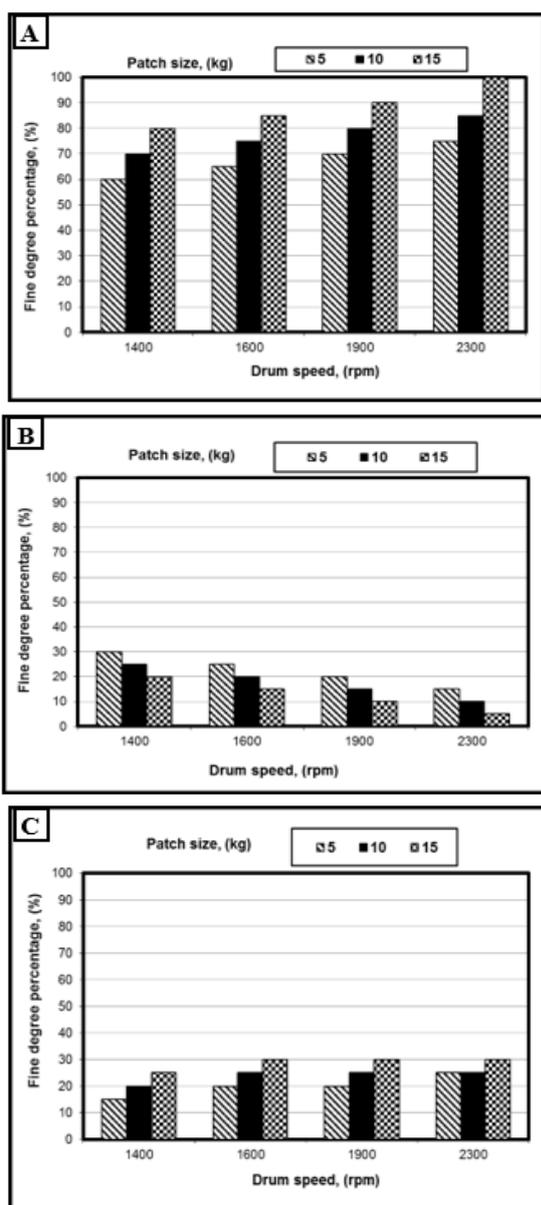
A: Screen diameter (3.5mm)   B: screen diameter (5mm)
C: Screen diameter (8.5mm)

Influence of drum speed on fines degree percentage at different patch sizes and different screen diameters.

With regard to the effect of drum speed on fines degree percentage, Fig. (5A) show that at screen diameter of 3.5mm, increasing drum speed from 1400 to 2300 rpm measured at different patch sizes of about 5, 10 and 15kg, increased fine grinding percentage from 60 to 80, from 65 to 85, from 70 to 90 and from 75 to 100 % respectively, while decreased medium grinding percentage from 40 to 20, from 35 to 15, from 30 to 10 and from 25 to 0.0%, respectively.

With regard to the effect of drum speed on fines degree percentage, Fig. (5B) show that at screen diameter of 5mm, increasing drum speed from 1400 to 2300 rpm measured at different patch sizes of about 5, 10 and 15kg,

increased medium grinding percentage from 70 to 80, from 75 to 85, from 80 to 90 and from 85 to 95 % respectively, while decreased fine grinding percentage from 30 to 20, from 25 to 15, from 20 to 10 and from 15 to 5%, respectively, With regard to the effect of drum speed on fines degree percentage, Fig. (5C) show that at Screen diameter of 8.5mm, increasing drum speed from 1400 to 2300 rpm measured at different patch sizes of about 5, 10 and 15kg, increased medium grinding percentage from 40 to 50, from 45 to 55, from 50 to 60 and from 55 to 65%, respectively, and increased fine grinding percentage from 15 to 25, from 20 to 30, from 20 to 30 and from 25 to 30 % respectively, while decreased fine grinding percentage from 45 to 25, from 35 to 15, from 30 to 10 and from 20 to 5 %, respectively.

Fig. 5. Effect of drum speed on machine fines degree at different patch sizes and different screen diameters.
A: Screen diameter (3.5mm)   B: screen diameter (5mm)
C: Screen diameter (8.5mm)

Influence of drum speed on specific energy at different patch sizes and different screen diameters.

Concerning the effect of drum speed on specific energy, Fig. (6A) show that, at screen diameter of 3.5 mm, increasing drum speed from 1400 to 1900 rpm measured at different patch sizes of about 5, 10, and 15kg, decreased specific energy from 12.1 to 8.9, from 9.7 to 7.8, and from 8.3 to 6.7kW.h/Mg, respectively. Any further increase in drum speed more than1900 up to 2300 rpm measured at the same patch sizes increased specific energy from 8.9 to 9.4, from 7.8 to 8.2 and from 6.7 to 7.1 kW.h/Mg, respectively. The higher values of drum speed more than the optimum values tend to increase the specific energy due to decrease machine productivity.

Concerning the effect of drum speed on specific energy, Fig. (6B) show that, at screen diameter of 5mm increasing drum speed from 1400 to 1900 rpm measured at different patch sizes of about 5, 10, and 15 kg, decreased specific energy from 4.9 to 4.2, from 4.4 to 4, and from 4.2 to 3.8kW.h/Mg, respectively. Any further increase in drum speed more than 1900 up to 2300 rpm measured at the same patch sizes increased specific energy from 4.2 to 4.4, from 4 to 4.1 and from 3.8 to 3.9 kW.h/Mg, respectively. The higher values of drum speed more than the optimum values tend to increase the specific energy due to decrease machine productivity.

Concerning the effect of drum speed on specific energy, Fig. (6C) show that, at screen diameter of 8.5 mm increasing drum speed from 1400 to 1900 rpm measured at different patch sizes of about 5, 10, and 15 kg, decreased specific energy from 3.9 to 3.4, from 3.6 to 3.2, and from 3.4 to 3.1 kW.h/Mg, respectively. Any further increase in drum speed more than1900 up to 2300 rpm measured at the same patch sizes increased specific energy from 3.4 to 3.6, from 3.2 to 3.3 and from 3.1 to 3.2 kW.h/Mg, respectively. The higher values of drum speed more than the optimum values tend to increase the specific energy due to decrease machine productivity.

Influence of drum speed on operational cost at different patch sizes and different screen diameters.

As the effect of drum speed on operational cost, Fig. (7A) show that, at screen diameter of 3.5 mm increasing drum speed from 1400 to 1900 rpm measured at different patch sizes of about 5, 10 and 15mm, decreased operational cost from 84.4 to 61.9, from 67.5 to 54 and from 57.8 to 46.9L.E/Mg, respectively. Any further increase in drum speed from 1900 to 2300rpm, operational cost will increase from 61.9 to 65.3, from 54 to 56.8 and from 46.9 to 49.1L.E/Mg. Both higher and lower values of drum speed more or less than the optimum value tend to increase operational cost due to the decrease in machine productivity.

As the effect of drum speed operational cost, Fig. (7B) show that, at screen diameter of 5 mm increasing drum speed from 1400 to 1900 rpm measured at different patch sizes of about 5, 10 and 15mm, decreased operational cost from 33.8 to 29.3, from 31 to 27.6 and from 29.3 to 26.3L.E/Mg, respectively. Any further increase in drum speed from 1900 to 2300rpm, operational cost will increase from 29.3 to 30.4, from 27.6 to 28.7 and from 26.3 to 27L.E/Mg. Both higher and lower values of drum speed more or less than the optimum value tend to increase operational cost due to the decrease in machine productivity.

As the effect of drum speed operational cost, Fig. (7C) show that, at screen diameter of 8.5 mm increasing drum speed from 1400 to 1900 rpm measured at different patch sizes of about 5, 10 and 15mm, decreased operational cost from 27 to 23.6, from 25.3 to 22.5 and from 23.6 to 21.8 L.E/Mg, respectively. Any further increase in drum speed from 1900 to 2300rpm, operational cost will increase from 23.6 to 24.8, from 22.5 to 23.1 and from 21.8 to 22.1L.E/Mg. Both higher and lower values of drum speed more or less than the optimum value tend to increase operational cost due to the decrease in machine productivity.
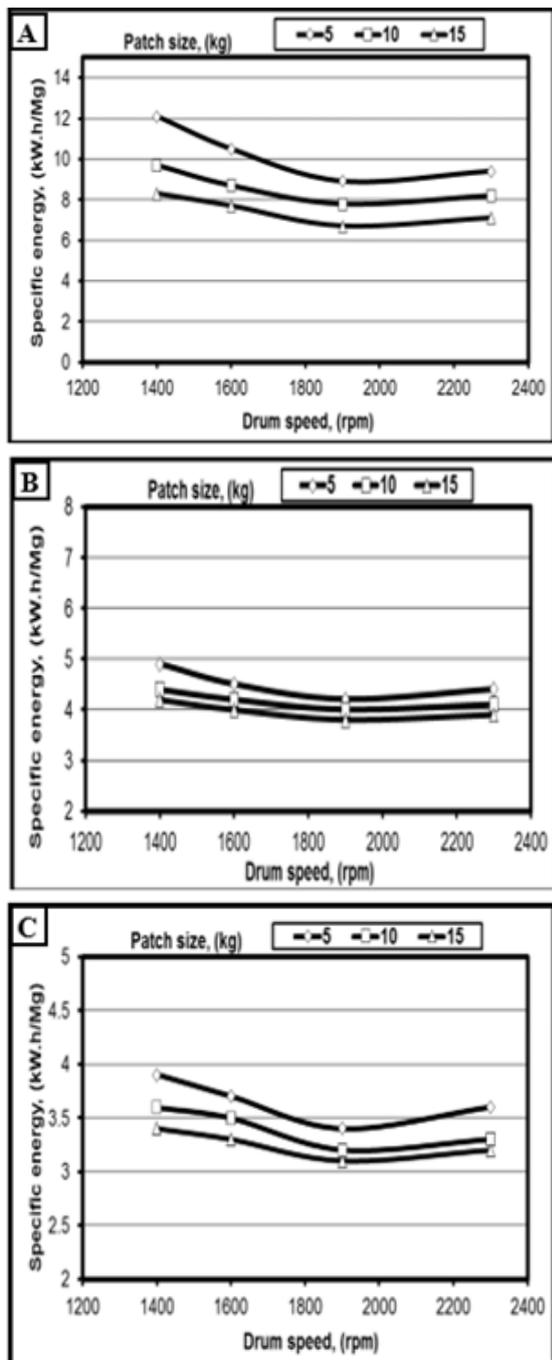

Fig. 6. Effect of drum speed on specific energy at different patch sizes and different screen diameters.
A: Screen diameter (3.5mm) B: screen diameter (5mm)
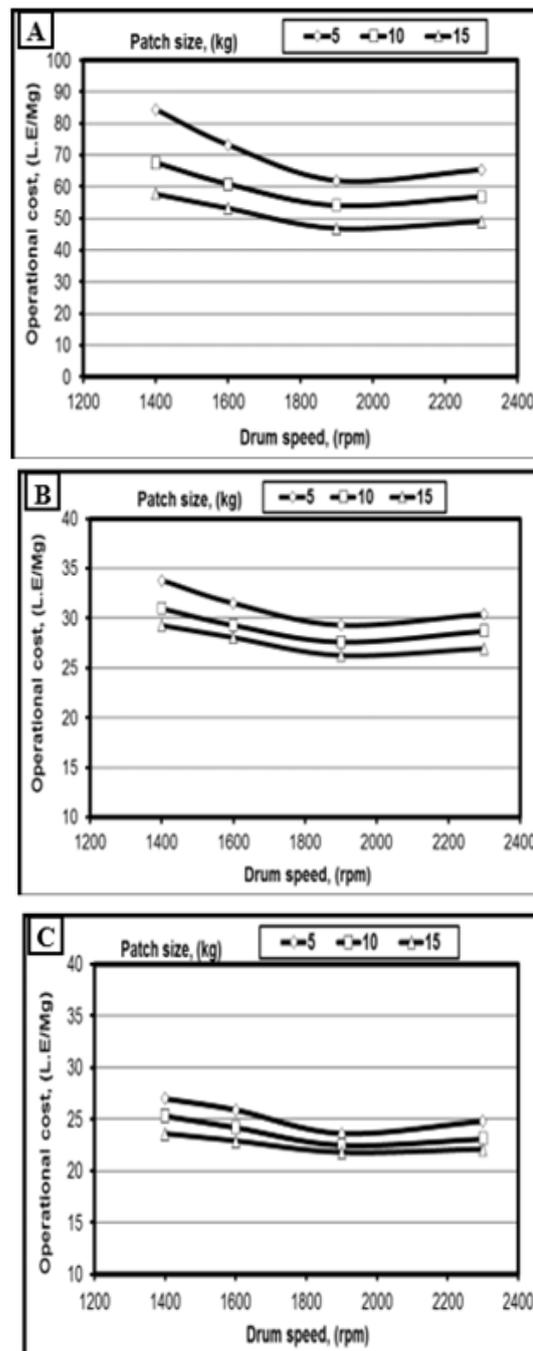C: Screen diameter (8.5mm)

Fig. 7. Effect of drum speed on operational cost at different patch sizes and different screen diameters.
A: Screen diameter (3.5mm) B: screen diameter (5mm)
C: Screen diameter (8.5mm)

CONCLUSION

A local grinding machine for grinding yellow maize grains for producing animal fodder was manufactured and evaluated taking into consideration the following indicators: machine productivity, particle size distribution (fineness degree), required power, specific energy and operational cost. The experimental results reveal that the highest value of machine productivity and highest machine efficiency were 931kg/h and 99.8%, while the lowest values of both specific energy and operational cost were 3.1kW.h/Mg and 21.8L.E./Mg respectively. The optimum operating parameters of the developed grinding machine were found

at 1900 rpm drum speed by using 8.5mm screen diameter with patch size of about 15kg.

It was recommended that using the locally manufactured grinding machine to grind the maize grains and get the highest productivity with the least energy consumed with the lowest operating costs under the following conditions: Drum speed of (1900rpm or 36m/s), screen hole diameter of (8.5mm), patch size of (15kg). To obtain the required fineness degree, the grinding machine can be operated using any screen diameter of (3.5, 5, 8.5mm).

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تصنيع وتقييم أداء آلة محلية الصنع لجرش حبوب الذرة
محب محمد أنيس الشرباصي وهنادي سامي سليمان سليمان
قسم الهندسة الزراعية – كلية الزراعة – جامعة دمياط.

تعتبر الذرة من أشهر أنواع الحبوب ويحتل المركز الثالث من حيث أهمية المحاصيل على مستوى العالم بعد الأرز والقمح، حيث تستخدم كغذاء للإنسان وكعلف للحيوانات، حيث تدخل الذرة الصفراء بنسبة (50-70%) من علف الدواجن بسبب قلة الألياف الموجودة بها ومحتواها العالي من الدهون مقارنة بحبوب الأعلاف الأخرى مما يجعلها سهلة الهضم لتغذية الدواجن. كما تعتبر الذرة من أغني الحبوب بالطاقة الحرارية حيث تحتوي علي نسبة عالية من فيتامين (أ). تعتبر تغذية قطعان الماشية أو الدواجن من أكبر المشكلات التي تواجه مربي الحيوانات والدواجن حيث تستهلك أكثر من 75% من إجمالي تكلفة الإنتاج فيميل المربين إلى استخدام آلات طحن صغيرة الحجم لإنتاج احتياجاتهم من الأعلاف ولإعداد وجبات الحيوانات والدواجن لأنها ملائمة لطحن مختلف أنواع الحبوب والعمل مع أي مادة وألياف قابلة للتفتيت. لذا تم تصنيع آلة محلية الصنع لجرش حبوب الذرة الصفراء بإحدى الورش الخاصة بمدينة الوسطاني— محافظة دمياط، لجرش حبوب الذرة لاستخدامها كعلف للحيوانات بهدف تحقيق التنمية الاقتصادية بأقل تكلفة ممكنة. تم تصنيع وتقييم آلة جرش حبوب الذرة بمدينة الوسطاني— محافظة دمياط خلال الفترة (من مارس إلى ديسمبر عام 2020م) وذلك للوصول إلى أفضل العوامل التشغيلية لتحقيق أعلي كفاءة وبأقل تكاليف ممكنة. وكانت أهداف الدراسة الآتي:تصنيع وتقييم أداء آلة محلية الصنع تناسب جرش حبوب الذرة. تحديد العوامل التشغيلية المثلى لكل من معدلات التلقيم وسرعة درفيل الطحن وقطر الغرابيل والتي تحقق أعلى كفاءة بأقل تكلفة لتشغيل الآلة. تقييم الآلة المصنعة محلياً من المنظور الاقتصادي. وقد أجريت التجارب العملية باستخدام المعاملات الآتية: ثلاث قيم مختلفة لكمية الحبوب في القادوس (معدل التلقيم) هي: (5، 10 و 15 كيلوجرام). أربع سرعات مختلفة لدرفيل الجرش هي: (1400، 1600، 1900 و 2300 لفة/دقيقة أو 26، 30، 36 و 43 م/ث). ثلاث قيم مختلفة لقطر الغرابيل (صدر الجرش) هي: (3.5، 5 و 8.5 ملليمتر). ولتقييم أداء آلة جرش الذرة المصنعة محلياً تم أخذ القياسات التالية: (إنتاجية الآلة، درجة النعومة والدرجة الوسط ودرجة الخشونة للحبوب المجروشة وكذلك الطاقة المستهلكة مع حساب تكاليف التشغيل). وقد أظهرت النتائج المتحصل عليها ما يلي: أعلي قيمة للإنتاجية كانت (931 كجم/ساعة عند سرعة جرش 1900 لفة/دقيقة وقطر غربال 8.5 ملليمتر بكمية حبوب 15 كيلوجرام). أقل قيمة للطاقة المستهلكة مع أقل قيمة لتكاليف تشغيل الآلة المصنعة كانت (3.1 كيلوات.س/ميجا جرام و21.8 جنيه/ميجا جرام)، على الترتيب عند نفس ظروف التشغيل السابقة. ومن ثَمَّ توصي الدراسة باستخدام آلة الجرش المصنعة محلياً لجرش حبوب الذرة لاستخدامها كعلف للحيوانات والحصول على أعلى إنتاجية وكفاءة بأقل طاقة مستهلكة مع أقل تكاليف تشغيل عند الظروف التالية: سرعة درفيل الجرش (1900 لفة/دقيقة أو 36 م/ث). قطر الغربال (8.5 ملليمتر). كمية الحبوب (15 كجم). وللحصول علي درجة النعومة المطلوبة يستخدم أي من الغرابيل بأقطار فتحات (3.5، 5، 8.5 ملليمتر).