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Manufacturing and Performance Evaluation of a Machine for Chopping Some Agricultural Residues

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ABSTRACT

Experiments were conducted to assess the performance of the chopping machine in order to use the final product for the production of animal feed and a variety of industrial products. The chopping machine's performance was tested using three different types of crop residues (rice straw, corn stalks, and cotton stalks), three different moisture contents for crop residues (wet base), and four different chopping knife speeds (1200, 1500, 1900 and 2200). Results showed that the highest machine productivity values were 0.436, 0.42 and 0.34 Mg/h, the highest fineness degree values were 81, 75 and 45%, the highest values of machine efficiency were 94, 96 and 95%, while the lowest specific energy values were 3.46, 5.29, 2.24 kW.h/Mg and the lowest operational cost values were 132.72, 138.1 and 170.1 L.E/Mg for rice straw, corn stalks and cotton stalks, respectively. The maximum values indicated were measured under the following conditions: Chopping knives speed at 1900 rpm equals 89.54 m/s, therefore feeding drums speed at 208 rpm equals 9.8 m/s for different agricultural residues containing moisture contents 6.76, 8.22 and 10.63% for rice straw, corn stalks and cotton stalks, respectively and constant knife angle of 10 degree and constant clearance between fixed and moving knives of 2 mm.

INTRODUCTION

Agricultural residues are considered a heavy burden on the environment, especially since improper disposal of these wastes reflects wrong practises that waste a valuable productive element available on agricultural lands, as it can be included in many industries such as manufacturing of organic fertilizers, feed and generation of clean energy, and even its recycling protects the environment from pollution; The crop residues must be cut into pieces using chopping machines to use in different purposes. It provides job opportunities for young people, thus improving the economic situation. In Egypt, during 2020 there are about 241 million Mg annually of the crop residues which the amount of rice straw is about 48 million Mg, the amount of corn stalks is about 62 million Mg and the amount of cotton stalks is about 4.9 million Mg **(FAO, 2020)**. Chopping machines need a large source of power, whether from the tractors whose fuel consumption is large, or an electric source, which is not available in all farms until now. **Younis et al. (2002)** constructed a chopping machine and utilized it to cut rice, cotton, and maize stalk residue. They discovered that at rotor speeds of 2200 and 1600 rpm, the highest required power and consumed energy were 11.77 kW and 12.99 kW.h/Mg, respectively. The increase in rotor speed from 1600 to 2000 rpm resulted in a 17.11% decrease in consumed energy; however the increase in rotate speed from 2000 to 2200 rpm resulted in a 12.9% increase in used energy. According to **El-Khateeb (2007)**, speed of the cutting head was generally increased to increase useful power from 2.19 to 3.86 kW, with a reduction in required unit energy from 1.87 to 1.37 kW.h/Mg and a reduction in cost of chopping machine from 16.33 to 7.22 L.E/Mg at several knives of 2 and a moisture level of 65% in the corn stalk. **El-Khateeb et al. (2010)** reported that Egypt's crop residue quantity was estimated to be 18.7-25 million Mg per year and if we try to recycle it, our national income could rise by about 1.6 billion LE per year. There are several benefits to supply food to animals in the shape of straw that has been chopped into little pieces, particularly when there is a lack of food. To increase straw's nutritional value by chopping it up into small pieces so digestive fluids may readily enter the examination of straw and therefore enhance digestion. **Elfatih et al. (2010)** improved and tested a rice straw chopping machine. They discovered that increasing the linear speed of the cutting drum from 56.6 m/s to 70.7 m/s improved cutting efficiency, chopper productivity, and power consumption by 3.7, 2.8, and 0.9%, 57.5, 55.9, and 41.7%, 36.8, 28.6, and 35.9%, respectively, while decreasing consumption of energy by 32.7, 38.4, and 9% for concave holes diameters of 35 mm, 25 mm and 9 mm, respectively. **Solomon-Tekeste (2012)** created a chopper with an engine to chop hay and crop byproducts. The machine's main components included a feed chopper, knives swinging in a revolving drum, a fixed-knife case with welded-on handles, stands and a screen. The machine test was carried out with the following three different drum speeds: 960, 1200, and 1400 rpm, as well as feed rates of 420, 540, and 660 kg/h. According to results, the optimal drum speed and feed rate values for both maize stalks were 1200 rpm and 540 kg/h, respectively. For maize stalks, using these optimal combinations, the average size reduction percentage was 92.0%. With an output rate of 420–660 kg/h and specific energy requirement of 11–20 kJ/kg output, the machine performed admirably. **EL-Attar et al. (2013)** mentioned that when the cutter head speed was increased from 22.1 to 35.3 m/s and the number of knives was increased from 2 to 8 tended to increase useful power from 2.19 to 3.86 kW, 2.19 to 2.94 kW, and 5.81 to 2.19 kW by increasing the moisture content of corn stalks from 35 to 65%, at 2 knives and a cutter head speed of 22.1 m/s. When the cutter speed increased from 22.1 to 35.3 m/s and the corn stalk moisture content increased from 35 to 65%, the unit energy in kW.h/Mg decreased from 5.19 to 2.91 kW.h/Mg and from 1.87 to 1.37 kW.h/Mg. Furthermore, by increasing the number of knives from 2 to 8, at 65% moisture content and 22.1 m/s cutter head speed, the unit energy increased from 1.87 to 2.65 kW.h/Mg. When the cutter head speed was increased from 22.1, 25.6, 29.2, and 35.3 m/s, at corn stalk moisture content of 65% and number of knives 8, the total chopping machine cost was found to be 16.33, 13.07, 9.63, and 7.22 L.E/Mg. **Radwan et al. (2016)** evaluated the effectiveness of the cutting machine for cutting peanut, sweet potato, and rice straw vines in order to make animal feed from the finished product. Two feeding drums with dimensions of 34 cm in length and a diameter of 7 cm were included with the cutting machine. Four hex-head bolts were used to secure the sharp blade to the steel shear. To move the materials for chopping in the direction of the outlet, the inclination-cutting blades act as a centrifugal fan. **EL-Attar et al. (2013)** said that, in general, increasing the cutter head speed from 22.1 to 35.3 m/s tends to increase the percentage of chopping length from 0.5 to 2.0 cm from 50 to 60%, the destruction degree from 28.7 to 38.2%, and the machine productivity from 1.32 to 2.81 Mg/h at 2 knives and a moisture content of 65.0% of the corn stalk. **Werby and Mousa (2017)** indicated that under the following ideal conditions, the fixed thresher machine can be successfully utilised for cutting and chopping onion leaves: For the two tested moisture values of 17.6 and 11.5%, the drum speed was 650 rpm, the feeding rate was 20 kg/min, and the percentages of cutting length (less than 30 mm) were 42 and 23%, respectively. **Mulatu (2021)** designed, fabricated, and evaluated the performance of the diesel-powered animal feed chopping machine. The machine contains: a) the feed inlet, where the feed is placed and prepared before being fed into the machine. b) Blade holder: It was built of machined steel that was 15 mm thick and 30 cm in diameter. c) Cutter blades: They were two in number, positioned at 180°, with a cutting depth of 3 cm and a cutting length of 10 cm, and they were meant to cut the feed to the appropriate lengths with acceptable regularity. d) Chopper House: The cutting assembly was composed of 3 mm-thick steel measuring 14 cm wide, 40 cm high, and 36 cm long. It was fastened to the frame stand assembly at four main points and supported the shaft and bearing assemblies. e) Base and stand assembly: This assembly was considered the machine's backbone because it housed all of the machine's operating parts. f) Power transmission: It was composed of a diesel engine, a belt, a shaft, and a pulley. Thus, the objectives of this research are to:

- Manufacture a local chopping machine for cutting some crop residues such as, rice straw, corn and cotton stalks with the desired cutting lengths for different uses.
- Determine the most appropriate operational factors affecting chopping machine performance such as, knives speed, feeding drums speed and moisture content of crop residue.

MATERIAL AND METHODS

A chopping machine was manufactured and constructed in a private workshop in Elbasayla village, Damietta city, Damietta governorate through year 2021/ 2022 to develop, construct and fabricate a chopping machine operated with small gasoline engine. The field experiments were carried out in Elharby street, Damietta city, Damietta governorate, Egypt to evaluate the performance of the constructed chopping machine for cutting rice straw, corn stalks and cotton stalks, to use the final product in producing animal feed and many industrial products.

2.1. MATERIALS:

2.1.1. The used crop residues:

In this study, three crop residues were used: (rice straw, corn and cotton stalks) with different initial moisture contents.

Some physical properties of the used residues were illustrated in Table 1.

2.1.2. Manufactured chopping machine:

The chopping machine was manufactured and evaluated for chopping rice straw, corn and cotton stalks.

Table1: Some physical properties of the crop residues.

tem	Rice straw (Giza 101)	Corn stalks (Giza 155)	Cotton stalks (Giza 87)
Stem diameter, mm	3	15	5
Stem length, mm	900	1750	1400
Mass of 10 stalk, kg	1.76	5.29	2.00
Number of branches	0	3	7
Average Initial moisture content, %	20.13	30.87	25.2

The main parts of the manufactured chopping machine are presented in Fig. (1) As following:

♦ Inlet opening: The inlet opening was made of iron sheet in trapezoidal shape with 60 cm in length and inclination angle of 12 degree at horizontal. The outer side of the inlet opening was 43 cm in height and 9 cm in width, while the inner side at the feeding drums was 24 cm in height and 17.5 cm in width. It was made to hold and guide the stalks to feeding drums.

♦ Feeding unit: The feeding unit includes two parts:

(a) Feeding drums: The chopping machine was provided with two feeding drums (drive and driven) like a gear to feed the crop residues towards the chopping mechanism. The feeding drums with 6 long grooves were made from iron with 8.1 cm in diameter and 23 cm in thickness. The drive feeding drum was fixed on shaft with38 cm in length and 1.5 cm in diameter, and the driven one was fixed on shaft with 34 cm length and 1.5 cm in diameter also. The feeding drums were powered from the drive gear (2) having dimension of (12, 10 and 1 cm) for outer diameter, inner diameter and thickness, respectively. The driven gear (4) having dimension of (6, 4 and 1 cm) for outer diameter, inner diameter and thickness, respectively as well as the speed ratio of feeding mechanism to chopping knives of (1 : 9).

(b) Assistant shaft: A serrate shaft made of iron with 34 cm in length and 1.5 cm in diameter was fixed above the driven feeding shaft with 6 cm to guide the crop stalks into the chopping mechanism easily.

♦ Chopping unit: The chopping unit was designed with the following parts:

(a) Moving knives: Three moving knives were with dimensions of (22.5, 7.5 and 1 cm) for length, width and thickness, respectively. The moving knifes were fixed on three drum bars using 4 Hex. HD. Bolt for each knife. The moving drum with dimensions of 19.5 and 8 cm for length, width, respectively was fixed on horizontal shaft made of iron with 3 cm in diameter and 45 cm in length, according to stress analysis on chopping shaft. The chopping shaft was laid on two horizontal bearing with dimensions of 8, 3 and 5 cm for outer diameter, inner diameter and thickness, respectively. The moving knives were fixed at constant knife angle of 10 degree to play as a centrifugal fan to throw out the chopping materials towards the outlet opening, and also reduce the power required of chopping operation.

(b) Fixed knife: A fixed knife with 31 cm in length, 3.5 cm in width and 1 cm in thickness was mounted on a steel bar using 2 Hex. HD. Bolts.

♦ Outlet opening: The outlet opening was made of steel sheet having dimensions of 29, 27 and 21 cm for length, width and height, respectively.

♦ Power source: The chopping machine was powered by a gasoline engine 16 hp (11.77 kW) at a maximum rotated speed of 2400 rpm.

♦ Machine frame: The machine frame was manufactured from hollow steel bars 5×5 cm and steel sheets with 1 mm in thickness. The overall frame dimensions were 121 cm in length, 83 cm in height and 81 cm in width and supplied with 4 ground rubber wheels having 20 cm in diameter.

♦ Power transmission: The machine was powered by a gasoline engine 16 hp (11.77 kW). The gasoline engine transmitted its rotating motion to the moving knives shaft by pulley (2) having dimension of 16, 12 and 3 cm for outer diameter, inner diameter and thickness and V-Belt (1) having dimension of 62 and 1 cm for length and in thickness. The rotating motion was transmitted from moving knives shaft to feeding drums by a middle shaft. The middle shaft was taken its motion from the moving knives shaft by pulley (3) having dimension of 28, 23 and 3 cm for outer diameter, inner diameter and thickness and V-belt (2) having dimension of 49 and 1 cm for length and thickness, respectively. The middle shaft was ended with a gear (1) having dimensions of 8 cm in outer diameter, 6 cm in inner diameter and 1 cm in thickness, respectively. The gear (1) transmitted its rotated motion to the gear (2) mounted on the feeding drum shaft. The feeding drum shaft transmitted the rotating motion to the driven feeding drum and the serrated assistant shaft by gear (3) having dimensions of 7 cm in outer diameter, 5 cm in inner diameter and 1 cm in thickness, respectively.

Design of chopping shaft considerations:

The chopping shaft supported by two bearings. The first bearing located beside the pulleys (2 and 4) on the chopping shaft, and the second one locating at the end of the chopping shaft. There are three main loads affecting the chopping shaft, the first load (F1) was due to weight of chopping drum with moving knives. The second load (F2) was transported from the weight of pulley (2) and the tension force on tight and slack side of its V-belt (1). The third load (F3) was transported from the weight of pulley (4) and the tension force on tight and slack side of its V-belt (2).

Fig. (2): Stress analysis on chopping shaft.

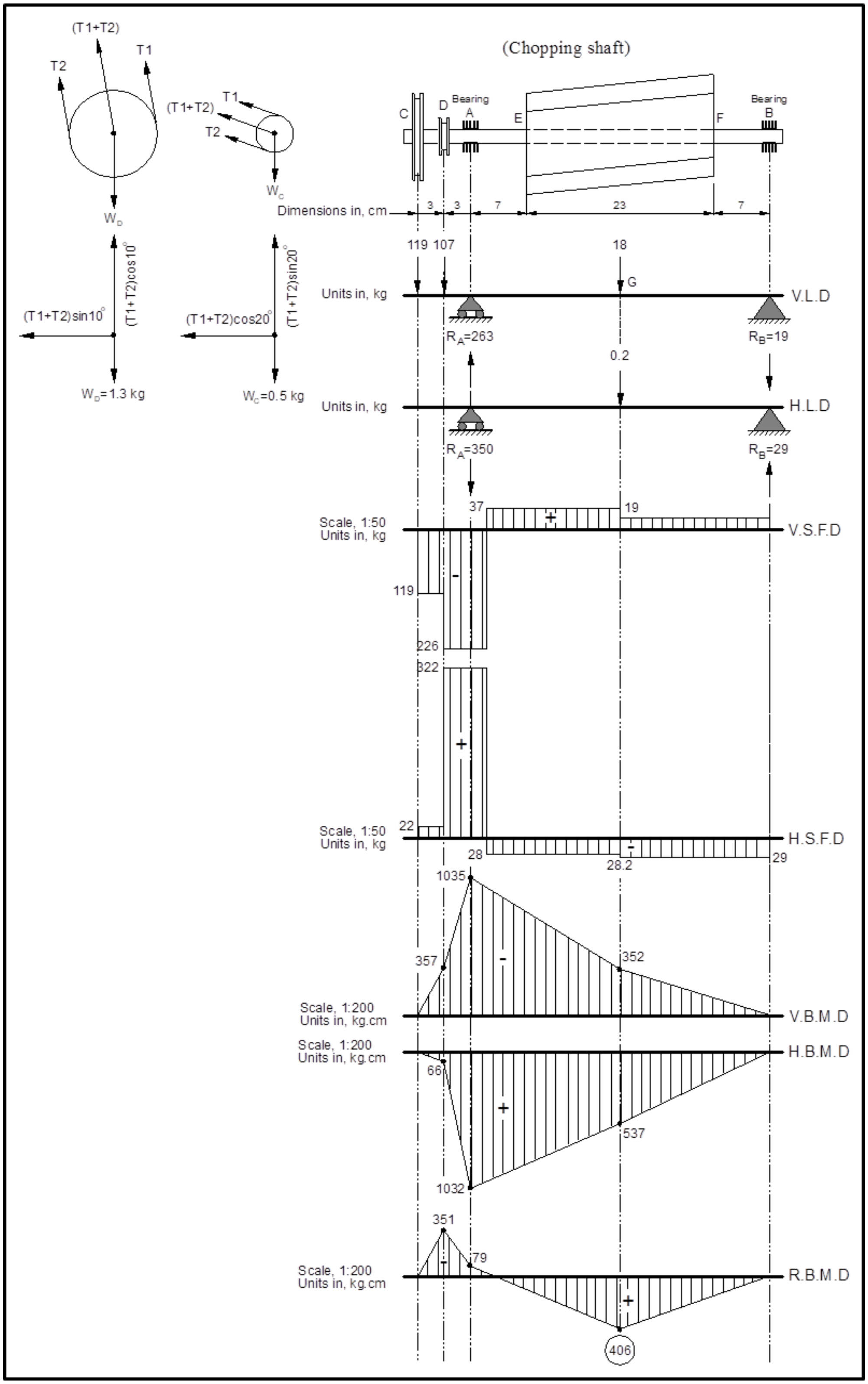
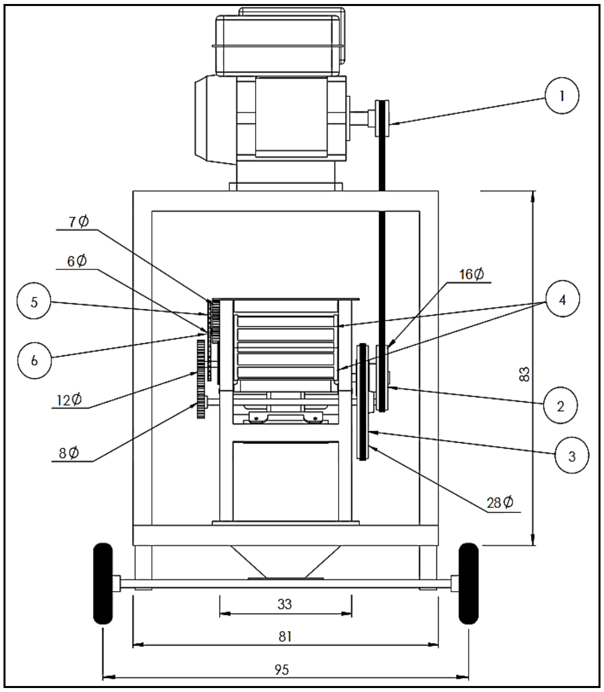
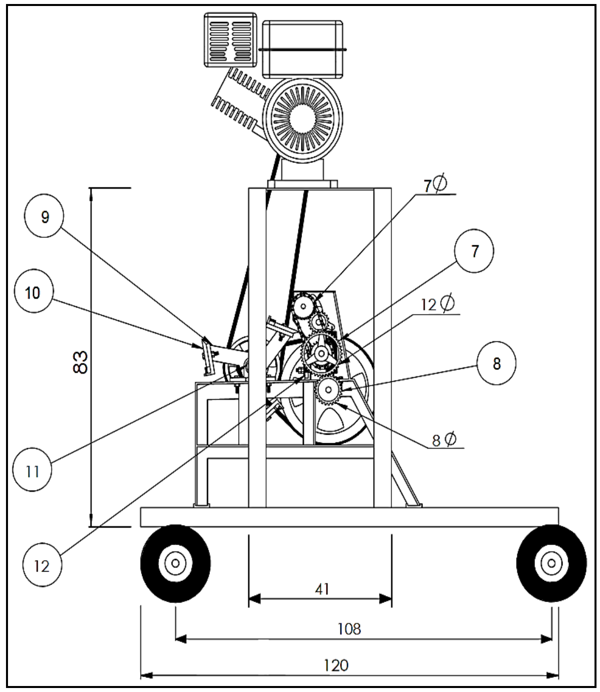


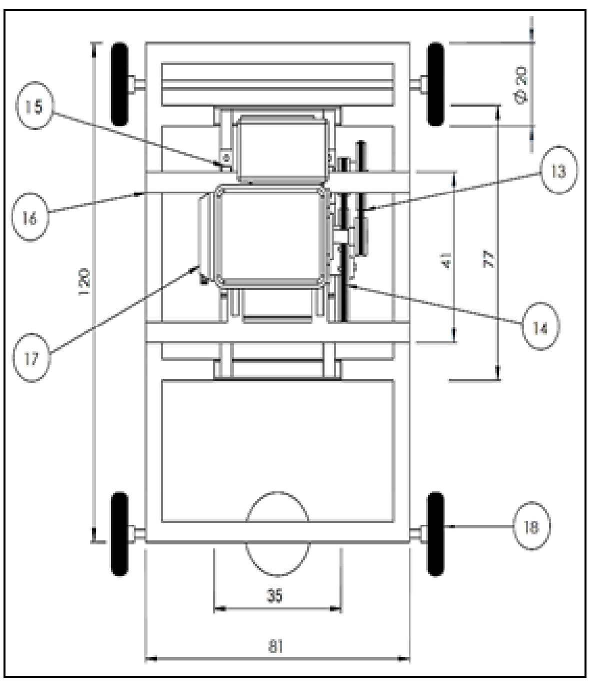
Fig. (1): A front view, side view and top view of the chopping machine.



Front view



Side view



Top view

No.	Part name	No. off
1	Pulley (1)	1
2	Pulley (2)	1
3	Pulley (3)	
4	Feeding drums	1
5	Gear (3)	1
6	Gear (4)	1
7	Gear (2)	1
8	Gear (1)	1
9	Moving drum	1
10	Moving knife	3
11	Knife shaft	1
12	Fixed knife	1
13	V-Belt (1)	1
14	V-Belt (2)	1
15	Bearing	2
16	Frame	1
17	Gasoline motor	1
18	Ground wheel	4

All Dimensions in, cm

These three loads are in to different planes and directions, as shown in Fig. (2). the chopping shaft under these loads is subjected to combine torsion and bending stresses. The diameter of the chopping shaft can be calculated according to the maximum shear theory, **(Khurmi and Gupta, 2007)** as following:

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

$$Z_{max} = \frac{16}{\pi d^3}\sqrt{K_m.M^2 + K_t.T^2}\text{ , kg.cm } (2)$$

Where: τmax = Maximum shear stress = 400 kg/cm2

τ = Shear stress, kg/cm2
Mb = Maximum bending moment, kg.
δ = Bending stress, kg/cm2
d = Diameter of shelling shaft, cm
T = Maximum torque, kg.cm
Kt = Shock factor for torsion, Kt = 2
Km = Shock factor for bending, Km = 2

The maximum bending moment and twisting torque on the chopping shaft equal 406 and 956 kg/cm2, respectively as shown in Fig. (2). Then the maximum shear theory is applied as follows:

$$\therefore 400 = \frac{16}{3.14d^3}\sqrt{2.(406)^2 + 2.(956)^2}\ (3)$$

$$\therefore 400 = \frac{16}{3.14d^3} \times 1468.86$$

$$\therefore d^3 = 18.71 \therefore d = 2.65\text{ cm} = 26.5\text{ mm (d was taken 30mm)}(4)$$

2.2. METHODS:

2.2.1. Preliminary experiments:

The preliminary experiments were carried out to evaluate the performance of the manufactured machine to be suitable for chopping crop residues. Some modifications were conducted in chopping units to obtain the desirable cutting length as following:

- The chopping moving knives were fixed on the chopping shaft at inclination angle of 10° to obtain high machine performance.
- The clearance between the rotating knives and fixed knife was adjusted at 2 mm to obtain high cutting and chopping efficiency.

2.2.2. Experimental conditions:

The main experiments were carried out to evaluate the performance of the chopping machine. The performance of the chopping machine was experimentally measured under the following parameters:

- Three different crop residues of (rice straw, corn and cotton stalks).
- Three different moisture contents (wet base) for each crop residues of (20.13, 13.55, 6.76%), (30.87, 11.33, 8.22%) and (25.2, 10.63, 8.04%) for rice straw, corn and cotton stalks, respectively.
- Four different chopping knife speeds of (1200, 1500, 1900, 2200 rpm), corresponding to (56.55, 70.69, 89.54, 10.37m/s), respectively and therefore be feeding drums speeds of (133, 170, 208, 240 rpm), corresponding to (6.27, 8.01, 9.8, 11.31 m/s), respectively.

2.2.3. Measurements and determinations:

The performance evaluation of the manufactured chopping machine for chopping rice straw, corn and cotton stalks were based on the following equations:

■ Machine productivity: The machine productivity was calculated from the following equation:

MP=W/T……… (5)

Where: MP: Machine productivity, Mg/h.
W: Mass of chopped residues, Mg.
T: Machine operating time, h.

■ Chopping efficiency: The cutting length of final product is an important parameter to evaluate the performance of cutting process. The chopping efficiency was estimated by using the following equation:

$\eta ch=(H_b-H_a)/H_b \times 100$……………(6)

Where:

ηch: Chopping efficiency, (%).
H_b: Mean plant height before cutting, (mm).
H_a: Mean stubble height after cutting, (mm).

■ Fineness degree (particle size distribution): A randomized sample after chopping process for each treatment was classified into three main categories according to chopping lengths:

- The first one is: Fine Chopping, FC (< 10 mm).
- The second is: Medium Chopping, MC (10-20 mm).
- The third is: Coarse Chopping, CC (> 20 mm).

■ Power requirements: To estimate the required engine power during chopping operation, the decrease in benzene fuel level in the fuel tank immediately after each treatment of chopping process was accurately measured.

The power required was calculated using the following formula:

$EP=[F.C(1/3600)\rho \times L.C.V \times 427 \times \eta_{thb} \times \eta_m \times 1/75 \times 1/1.36]$...(7)

Where: EP: Engine power, kW.
F.C: Fuel consumption rate, l/h.
ρ: Density of fuel, kg/l, (for Otto engine = 0.72).
L.C.V: Lower calorific value of fuel, k.cal/kg, for benzene = 11.000 k.cal/kg.
η_{thb}: Thermal efficiency of the engine, assumed 25 % for Otto engine.
η_m: Mechanical efficiency of the engine, assumed 75 % for Otto engine.
427:Thermo-mechanical equivalent, kg.m/k.cal.

So, the engine power can be calculated as following:

Engine Power =1.96 F.C, kW

■ Specific energy: Specific energy was estimated using the following formula:

SE=EP/MP, kW.h/Mg ………… (8)

■ Operational cost: The operational cost for the chopping operation was calculated according to the following formula:

Cop=C/MP…………… (9)

Where: Cop: Operational cost, L.E/ Mg.

C: Machine hourly cost, L.E/h.

The hourly cost of chopping machine was determined using the following formula:

C=p/h (1/a+ i/2+t+r)+(1.2 W.S.F)+m/192……………(10)

Where: C: Cost per hour of operation, L.E/h

P: Estimated price of the machine, L.E.

h: Yearly working hours, h/year.

a: Life expectancy of the machine, years.

i: Annual interest rate, rate/year.

t: Annual taxes and overheads ratio, %.

W: Engine power, kW.

r: Annual repair and maintenance rate, %.

F: Fuel price, L.E/l.

S: Specific fuel consumption, l/kW.h.

m: Labor monthly salary, L.E.

1.2: Factor accounting for ratio of rated power.

192: Reasonable estimation of monthly working hours.

RESULTS AND DISCUSSION

The obtained results will be discussed under the following items:

Influence of chopping knives speed on machine productivity at three different moisture contents for different crop residues.

The effect of knives speed on machine productivity is given in **Fig. (3)**. concerning to rice straw, the obtained results show that increasing knives speed from 1200 to1900 rpm measured at different moisture contents of 20.13, 13.55 and 6.76% increased machine productivity from 0.15 to 0.28, from 0.211 to 0.35 and from 0.309 to 0.437 Mg/h, respectively. Any further increase in knives speed more than 1900 up to 2200 rpm measured at the same previous moisture contents decreased machine productivity from 0.28 to 0.267, from 0.35 to 0.3 and from 0.437 to 0.4 Mg/h. Respecting to corn stalks, the obtained results show that increasing knives speed from 1200 to 1900 rpm measured at different moisture contents of 30.87, 11.33 and 8.22% increased machine productivity from 0.139 to 0.270, from 0.190 to 0.31 and from 0.26 to 0.42 Mg/h, respectively. The further increase in knives speed more than 1900 up to 2200 rpm measured at the same previous moisture contents, decreased machine productivity from 0.42 to0.4, from 0.33 to 0.304 and from 0.27 to 0.259 Mg/h. Relating to cotton stalks, the obtained results show that increasing knives speed from 1200 to 1900 rpm measured at different moisture contents of 25.2, 10.63 and 8.04% increased machine productivity from 0.123 to 0.28, from 0.182 to 0.341 and from 0.101 to 0.193 Mg/h, respectively. The further increase in knives speed more than 1900 up to 2200 rpm measured at the same previous moisture contents, decreased machine productivity from 0.28 to 0.269, from 0.341 to 0.321 and from 0.193 to 0.180 Mg/h.

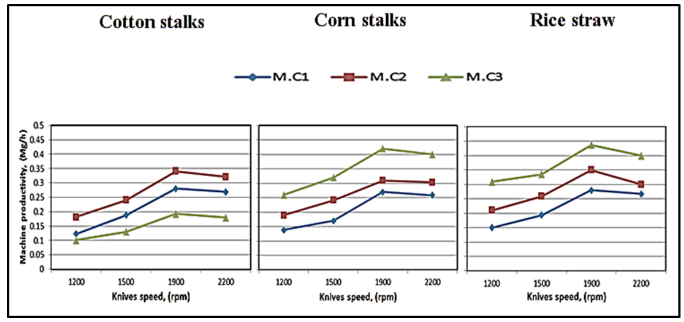


Fig. (3): Effect of chopping knives speed on machine productivity at three different moisture contents for different crop residues.

These results agree with **Radwan et al. (2016)**, increasing drum speed increased machine productivity from 1150 to 1520 rpm; any further increase in drum speed up to 1628 rpm machine productivity decreased.

Influence of chopping knives speed on chopping efficiency at three different moisture contents for different crop residues.

The effect of knives speed on machine efficiency is given in **Fig. (4)**. Related to rice straw, the results show that increasing knives speed from 1200 to 2200 rpm measured at different moisture contents of 20.13, 13.55 and 6.76% increased machine efficiency from 40 to 82, from 50.6 to 87 and from 60 to 94%, respectively. Concerning to corn stalks, the obtained results show that increasing knives speed from 1200 to 2200 rpm measured at different moisture contents of 30.87, 11.33 and 8.22% increased machine efficiency from 50 to 80, from 60 to 85 and from 70 to 96%, respectively. With respect to cotton stalks, the obtained results show that increasing knives speed from 1200 to 2200 rpm measured at different moisture contents of 25.2, 10.63 and 8.04% increased machine efficiency from 52 to 80, from 60 to91 and from 66 to 95%, respectively.

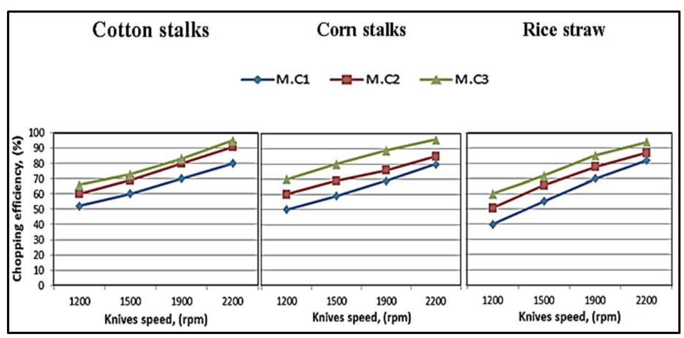
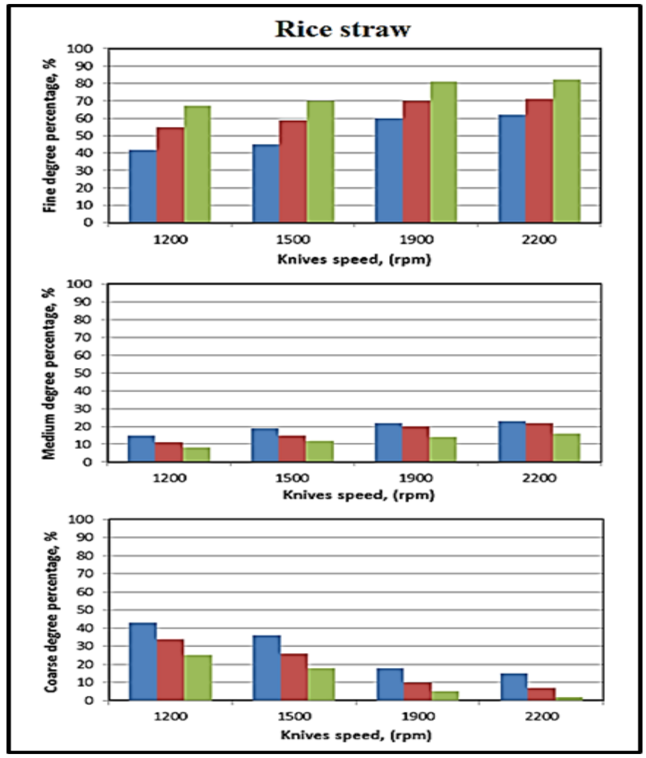


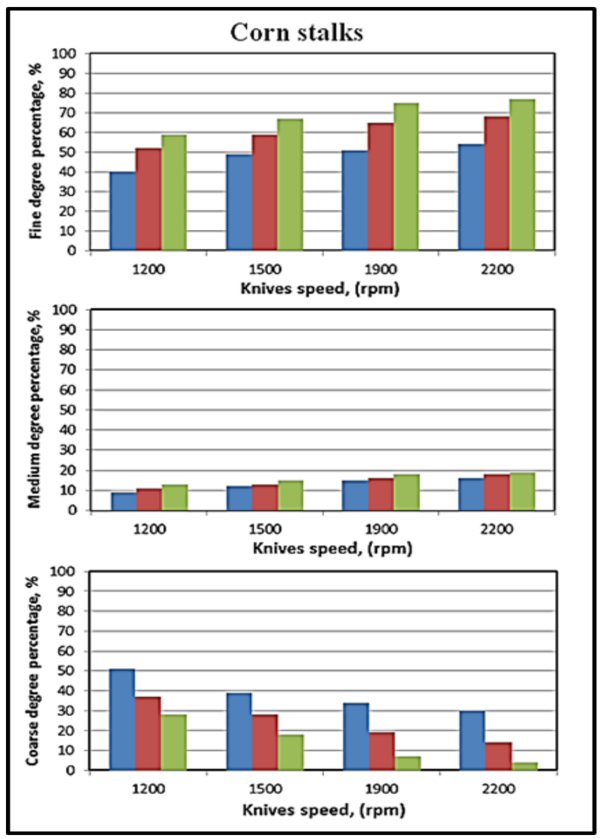
Fig. (4): Effect of chopping knives speed on chopping efficiency at three different moisture contents for different crop residues.

These results are consistent with the findings of **El Ashry et al. (2004)**, who stated that chopping efficiency increased as the knife rotation speed increased, while the chopping efficiency decreased with increased average moisture content of straw. The cutting efficiency increased with decreased moisture content and increased cutting drum speed.

Influence of chopping knives speed on fineness degree at three different moisture contents for different crop residues.

The effect of knives speed on fineness degree is given in **Fig. (5)**. Concerning to rice straw, the obtained results show that increasing knives speed from 1200 to 2200 rpm measured at different moisture contents of 20.13, 13.55 and 6.76% increased fine degree percentage from 42 to 62, from 55 to 59 and from 67 to 82%, respectively, also increased medium degree percentage from 15 to 23, from 11 to 22 and from 8 to 16%, respectively. While decreased coarse degree percentage from 43 to 15, from 34 to 7 and from 25 to 2%, respectively. Respecting to corn stalks, the obtained results show that increasing knives speed from 1200 to 2200 rpm measured at different moisture contents of 30.87, 11.33 and 8.22% increased fine degree percentage from 40 to 54, from 52 to 68 and 59 to 77% respectively, also increased medium degree percentage from 9 to 16, from 11 to 18 and from 13 to 19% respectively, while decreased coarse degree percentage from 51 to 30, from 37 to 14 and from 28 to 4%, respectively. Concerning to cotton stalks, the obtained results show that increasing knives speed from 1200 to 2200 rpm measured at different moisture contents of25.2, 10.63 and 8.04% increased fine degree percentage from 30 to 45, from 36 to 47 and from 33 to 46%, respectively, also increased medium degree percentage from 23 to 37, from 34 to 49 and from 30 to 44%, respectively, while decreased coarse degree percentage from 47 to 18, from 30 to 4 and from 37 to 10%, respectively.





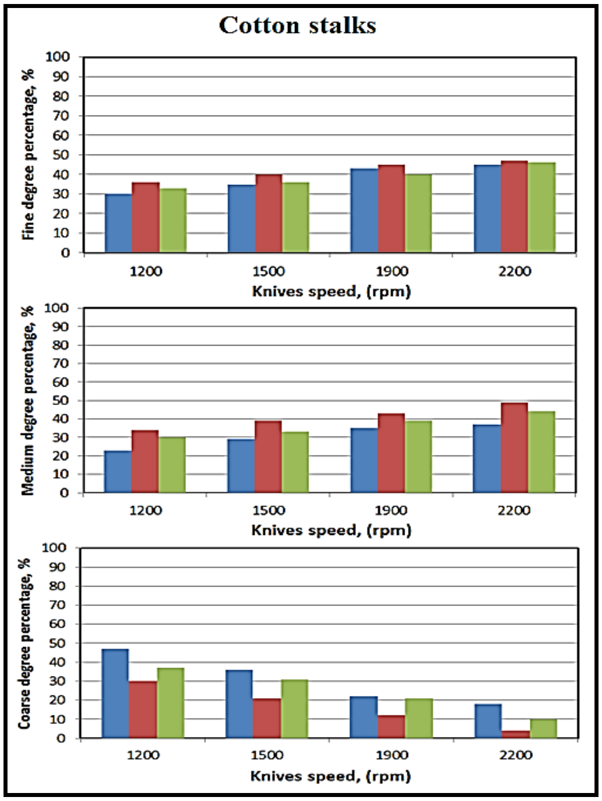


Fig. (5): Effect of chopping knives speed on fineness degree at different moisture contents.

These results agree with **El-Sharabasy and Badr (2014)**, increasing drum speed from 1000 to 1400 rpm measured at different feed rates of about 500, 600, 700 and 800 kg/h, increased fine milled percentage, also increased medium milled percentage, while decreased coarse milled percentage. The fineness degree increased by increasing drum speed due to the increase in chopping forces and friction of the rice straw, corn stalks and cotton stalks on the cutter-head.

Influence of chopping knives speed on specific energy at three different moisture contents for different crop residues.

The effect of knives speed on specific energy is given in **Fig (6)**. Relating to rice straw, the obtained results show that increasing knives speed from 1200 to 1900 rpm measured at different moisture contents of 20.13, 13.55 and 6.76% decreased specific energy from 9.03 to 4.9, from 7.98 to 4.52 and from 6.34 to3.46 kW.h/Mg, respectively. Any further increase in knives speed more than 1900 up to 2200 rpm measured at the same moisture contents increased specific energy from 4.9 to 5.42, from 4.52 to 4.87 and from 3.46 to3.91kW.h/Mg. Concerning to corn stalks, the obtained results show that increasing knives speed from 1200 to 1900 rpm measured at different moisture contents of 30.87, 11.33 and 8.22% decreased specific energy from 12 to 7.65, from 11 to 7 and from 10 to5.29kW.h/Mg, respectively. The further increase in knives speed more than 1900 up to 2200 rpm measured at the same moisture contents increased specific energy from 7.65 to 7.81, from 7 to 7.35 and from 5.29 to 5.53kW.h/Mg. In relation to cotton stalks, the obtained results show that increasing knives speed from1200 to 1900 rpm measured at different moisture contents of 25.2, 10.63 and 8.04% decreased specific energy from 7.05 to 3.78, from 5.08 to 2.24 and from 10.33 to5.3 kW.h/Mg, respectively. The further increase in knives speed more than 1900 up to 2200 rpm measured at the same previous moisture contents increased specific energy from 3.78 to 4, from 2.24 to 2.36 and from 5.3 to5.69 kW.h/Mg.

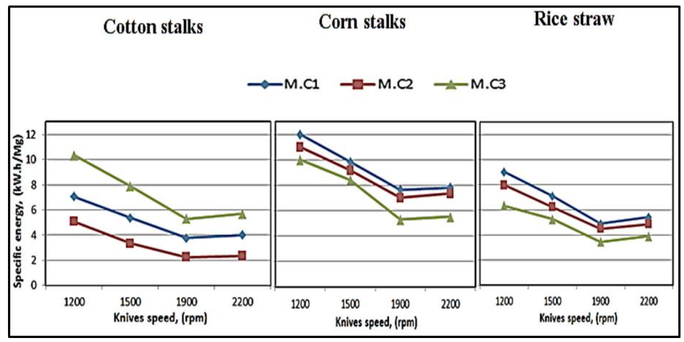


Fig. (6): Effect of chopping knives speed on specific energy at three different moisture contents for different crop residues.

The data are consistent with **El Shal and El Didamony (2018)** who stated that increasing chopping speed from 1650 to 2150 rpm, the specific energy requirement decreased. Increasing the chopping speed from 2150 to 2400 rpm caused an increase in the specific energy requirement at moisture contents of 60, 70 and 77 %, respectively.

Influence of chopping knives speed on operational cost at three different moisture contents for different crop residues.

The effect of knives speed on operational cost measured is given in **Fig. (7)**. As regard to rice straw, the results show that increasing knives speed from 1200 to 1900 rpm measured at different moisture contents of 20.13, 13.55 and 6.76% decreased operational cost from 386.67 to 207.14, from 276.19 to 165.71 and from 187.7 to 132.72 L.E/Mg, respectively. Any further increase in knives speed more than 1900 up to 2200 rpm measured at the same previous moisture contents increased operational cost from 207.14 to 217.23, from 165.71 to 193.33 and from 132.72 to 145 L.E/Mg. In connection with corn stalks, the obtained results show that increasing knives speed from 1200 to 1900 rpm measured at different moisture contents of 30.87, 11.33 and 8.22% decreased operational cost from 417.27 to 214.81, from 305.26 to 187.1 and from 223.1 to 138.1 L.E/Mg, respectively. Any further increase in knives speed more than 1900 up to 2200 rpm measured at the same moisture contents increased operational cost from 214.81 to 223.94, from 187.1 to 190.79 and from 138.1 to 145 L.E/Mg. With respect to cotton stalks, obtained results show that increasing knives speed from 1200 to 1900 rpm measured at different moisture contents of 25.2, 10.63 and 8.04% decreased operational cost from 471.54 to 207.14, from 318.68 to 170.09 and from 574.25 to 300.52 L.E/Mg, respectively. Any further increase in knives speed more than 1900 up to 2200 rpm measured at the same moisture contents increased operational cost from 207.14 to 215.61, from 170.09 to 181.25 and from 300.52 to 322.22 L.E/Mg.

These results agree with **Radwan et al. (2016)** who stated that both higher and lower values of cutting drum speed more or less than the optimum value tend to increase operational cost

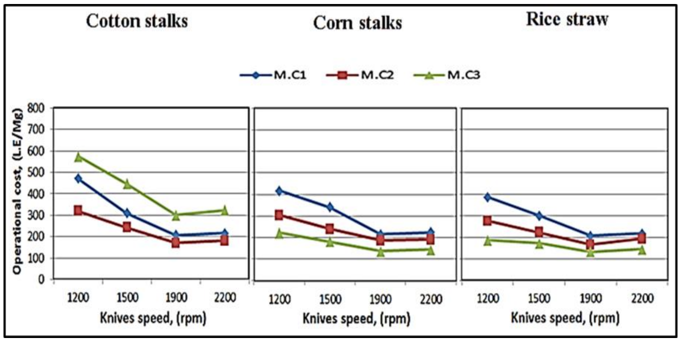


Fig. (7): Effect of chopping knives speed on operational cost at three different moisture contents for different crop residues.

due to the decrease in machine productivity concerning the optimum value.

CONCLUSION

This study recommends using a locally manufactured machine to chop these crops and get the highest productivity and efficiency with the least energy consumed with the lowest operating costs. The obtained results reveal that the highest values of machine productivity were 0.436, 0.42 and 0.341 Mg/h, the highest values of fineness degree were 82, 78 and 41%, the highest values of machine efficiency were 94, 96 and 95%, the lowest values of specific energy were 3.46, 5.29, 2.24 kW.h/Mg and the lowest values of operational cost were 132.72, 138.1 and 170.1 L.E/Mg for rice straw, corn stalks and cotton stalks, respectively under the following conditions: chopping knives speed of 1900 rpm corresponding to 89.54 m/s, therefore be feeding drums speed 208 rpm corresponding to 9.8 m/s with moisture contents 6.76, 8.22 and 10.63% for rice straw, corn stalks and cotton stalks, respectively, constant knife angle of 10 degree and constant clearance between fixed and moving knives of 2 mm.

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CONFLICT OF INTEREST:

The authors declare that they have no conflict of interest.

AUTHORS CONTRIBUTION

EL-sharabasy, M. M. A., and Nada Y. Gohar developed the concept of the manuscript. Nada wrote the manuscript. All authors checked and confirmed the final revised manuscript.

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تصنيع وتقييم أداء آلة لتقطيع بعض المخلفات الزراعية

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الملخص العربى

تعتبر المخلفات الزراعية في المرحلة الحالية عبئًا ثقيلًا على البيئة، خاصة وأن التخلص غير السليم من هذه المخلفات يعكس ممارسات خاطئة تتمثل في إهدار عنصر إنتاجي قيم متاح في الأراضي الزراعية. حيث تدخل المخلفات الزراعية في العديد من الصناعات مثل صناعة الأسمدة العضوية والأعلاف والطاقة النظيفة فإعادة تدويرها تحمي البيئة من التلوث؛ توفر فرص عمل للشباب، وبالتالي تحسين الوضع الاقتصادي. يجب تقطيع بقايا المحاصيل إلى قطع صغيرة باستخدام آلات التقطيع لاستخدامها في الأغراض المختلفة. تحتاج ماكينات التقطيع إلى مصدر طاقة كبير سواء من الجرار الذي يكون استهلاكه من الوقود كبيرًا أو مصدرًا كهربائيًا وهو غير متوفر في جميع المزارع حتى الآن. لحل مشكلة مصدر الطاقة، تم استخدام محرك بنزين استهلاكه قليل وفي نفس الوقت يعطي طاقة عالية، ويمكن نقل الآلة إلى أي مكان بسهولة عوضاً عن استخدام الطاقة الكهربائية أو الجرارات الزراعية. تم تصنيع ماكينة التقطيع من مواد أولية محلية لتقليل تكاليف الإنتاج وإتاحتها للمزارعين بأسعار مناسبة. تمت عملية التصنيع بإحدى الورش الخاصة بقرية البصايلة - مركز دمياط - محافظة دمياط من خامات محلية الصنع بغية تحقيق التنمية الاقتصادية بأقل تكلفة ممكنة. تم تنفيذ التجارب العملية بالشارع الحربى - مركز دمياط لتقييم أداء هذه الآلة للوصول إلى أفضل القيم التشغيلية لتحقيق أعلى إنتاجية بأقل تكلفة ممكنة.
وكانت أهداف هذا البحث كالآتى:

1. تصنيع آلة محلية لتقطيع مخلفات بعض المحاصيل قش الأرز , سيقان الذرة والقطن بأطوال القطع المطلوبة للاستخدامات المختلفة.
2. تحديد أنسب العوامل التشغيلية لكل من سرعة درفيل التقطيع وسرعة درفيل التغذية والمحتوى الرطوبى لكل مخلف من المحاصيل والتى تحقق أعلى كفاءة بأقل تكلفة تشغيل.
3. تقييم الآلة المصنعة محلياً من وجهة النظر الاقتصادية.

ولتقييم أداء الآلة تم أخذ بعض المعاملات التالية في الاعتبار :

- ثلاثة أنواع مختلفة من مخلفات المحاصيل هي: (قش الأرز ، سيقان الذرة والقطن).
- ثلاثة مستويات للمحتوى الرطوبى (على أساس رطب) لكل مخلف هي: (20.13 ، 13.55 ، 6.76٪) (30.87 ، 11.33 ، 8.22٪) (25.2 ، 10.63 ، 8.04٪) لقش الأرز ، سيقان الذرة والقطن، على التوالي .
- أربع سرعات مختلفة لسكاكين التقطيع هي: (1200 ، 1500 ، 1900 ، 2200 لفة/دقيقة) (56.55 ، 70.69 ، 89.54 ، 10.37 م / ث), على التوالي عند سرعات مختلفة لاسطوانات التغذية (133 ، 170 ، 208 ، 240 لفة/ددقيقة) (6.27 ، 8.01 ، 9.8 ، 11.31 م/ث)، على التوالي .

ومن خلال التجارب العملية تم الحصول على النتائج التالية:

- أعلى قيمة للإنتاجية وكفاءة التقطيع ودرجة النعومة كانت0.436) , 0.42, 0.34 ميجاجرام/ساعة) و (94, 96, 95%) و (81, 75, 45%) عند سرعة سكاكين التقطيع 1900 لفة/د ومحتويات رطوبة 6.76 ، 8.22 و 10.63% لقش الأرز وسيقان الذرة والقطن، على الترتيب
- أقل قيمة للطاقة المستهلكة مع أقل قيمة لتكاليف تشغيل الآلة المصنعة كانت (3.46, 5.29, 2.24 كيلووات.ساعة/ميجاجرام) و(132.72, 138.1, 170.1 جنيهاً/ميجاجرام) لقش الأرز ، سيقان الذرة والقطن، على الترتيب عند نفس ظروف التشغيل السابقة .

ومن ثمَّ توصى الدراسة باستخدام الآلة المصنعة محلياً لتقطيع مخلفات المحاصيل والحصول على أعلى إنتاجية وكفاءة بأقل طاقة مستهلكة مع أقل تكاليف تشغيل عند الظروف التالية :

- سرعة سكاكين التقطيع 1900 لفة/د (89.54 م/ث) عند سرعة درفيل التغذية 208 لفة/د (9.8 م/ث) .
- محتويات رطوبة 6.76 ، 8.22 و 10.63% لقش الأرز وسيقان الذرة والقطن، على الترتيب.
- خلوص بين السكينة المتحركة والثابتة 2 مم وزاوية ميل السكينة المتحركة 10 درجة لجميع أنواع المخلفات تحت الدراسة.

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