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УДК 631.363.2

THE EFFECT OF THE ROTATIONAL SPEED AND MOISTURE CONTENT IN CHOPPING PROCESS

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Keywords: chopping, rotational speed of knives , moisture content.

Abstract. There are many factors in the process of chopping animal feed like rotational speed of knives, moisture content , number of knives and feeding rate...etc. But in this article we will focus the effect of the rotational speed of knives and moisture content on the requirements of the process of chopping processing and chopping.

Introduction. Animal feeding is one of the most serious problems facing animal producer and it can be solved by selecting the proper animal diet in the acceptable phase. A potentially serious economic problem in Egypt is the extreme shortage in animal feeds. Such problem appears to be growing rather than diminishing in magnitude or even stabilizing. conventional feeds are not entirely satisfactory because of their considerable high price. Moreover, green forage are only available in extremely low quantities in summer, and the conventional dry roughages are of limited quantities. Furthermore the present available animal feeds, in general, could hardly suffice the requirements of about 60% of the existing animal population (cattle, buffalo, sheep and goats). Thus, silage process was hoped to participate in solving the problem of feed shortage of livestock [1, 2, 3, 4].

Animal feedstuff is a very important aspect of livestock husbandry as it is a major limiting factor in the rearing of animals to meet the increasing demand for animal protein, milk, hides, and skin and other products [5,6, 7].

The effect of cutting velocity on the fuel consumption. It was found that the fuel consumption increases with increasing the cutting velocity [8, 9].

The power consumption for cutting different residues was increased with increasing cutting and feeding speed. The minimum values of power consumption were (13.86, 15.24, and 15.66 kW) noticed for cutting corn stalks, rice straw and cotton stalks respectively at 24.08 m/s cutting speed and 1.0 m/s feeding speed. The maximum values of power consumption were (22.97, 23.92 and 25.82 kW) for cutting corn stalks, rice straw and cotton stalks respectively at 43.35 m/s cutting speed and 2.5 m/s feeding speed [10].

Developed chopping machine and used it for cutting residues of rice, cotton and maize. The increasing of rotor speed from 1600 to 2000 rpm caused a decrease of consumed energy by 17.11%. While the increasing of rotor speed from 2000 to 2200 rpm caused an increase of consumed energy by 12.9% [11].

The relationship between cutting drum speed and chopper productivity at different concave holes diameter for cutting rice straw. Chopper productivity increased by increasing the cutting drum speed. By increasing the cutting drum speed from 56.6 m/s to 70.7 m/s, the productivity increased from 489 kg/h to 1150 kg/h, from 430 kg/h to 976 kg/h, and from 350 kg/h to 600 kg/h for 35 mm, 25 mm, and 9 mm concave hole diameter, respectively [12].

Illustrated that the cutting speed must range between 15 to 30 m/sec for the suitable hay shredding. He also mentioned that the speeds over than the optimum speed range caused a rapid increasing of specific energy consumption [13].

Investigated the effect of plant moisture content on the performance parameters with different mechanical methods of cutting and chopping cotton. stalks They concluded that by increasing the moisture content the cutting efficiency could be increased, which means decreasing of the power requirement [14].

The cutting corn stalks at moisture content of 40.22%, cutterhead speed of 27.65 m/s and feeding mechanism speed of 0.41 m/min produced the maximum value of unit energy (2.08 KW.h/Mg). Meanwhile, the minimum value of cutting length (12.24 mm) was obtained with the same treatments at corn moisture content of 62.82 % [15].

The plant moisture content had very little effect on shearing energy for the condition of a sharp blade. As the blade became dull, the effect of the moisture was more pronounced [16].

Research objective. This study aimed essentially to evaluate the performance of chopping machine at different levels of corn moisture content and different levels of knives rotational speed.

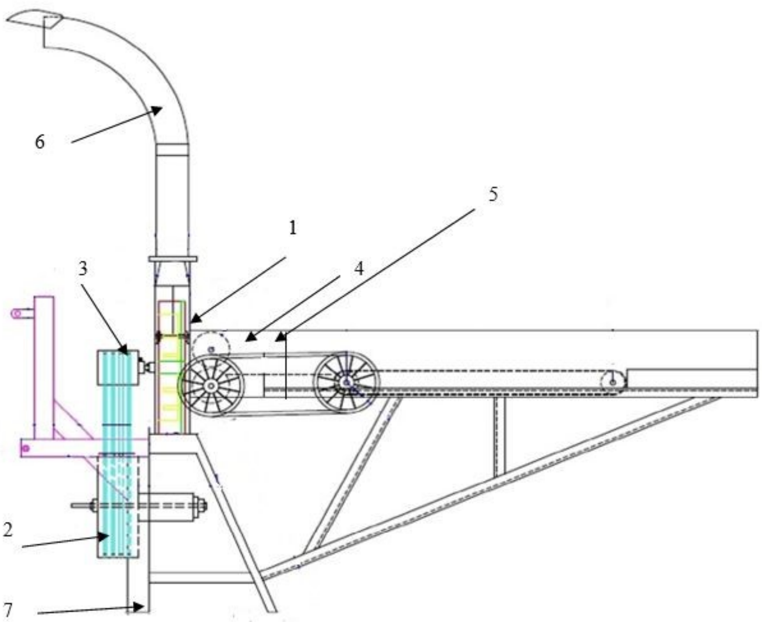
Materials and methods.

The study focused and concerned with the effect of changing two main factors which were; cutting speed and corn moisture content during the chopping process.

- Five different levels of cutting speed were changed which were 1200, 1400, 1600, 1800 and 2000 rpm. The values of the corresponding speeds were calculated according to the value of the transmission ratio of the gear box used in transfer the rotational speed to all moved member of the chopping machine.
- Three levels of corn moisture content were considered. Between each two consecutive levels, three days were left and the moisture content of corn was measured with the gravitational method. The values of the tested corn moisture content were 73.45, 64.19 and 45.11%.

The cutting machine, that used in this work, was presented schematically in fig. (1) represents an image of chopper machine in work. The main equipment which used in this work was chopper machine.

The cutting knives from a spring steel were sharpened at an angle of 30° to be used as a chopping member. In fig. (2) represent an image of the cutting disk of the chopping machine.



1 - Cutter head; 2 - Driver pulley; 3 - Driven pulley; 4 - Feeding drum; 5 - Feeding tray; 6 - Duct; 7 - Main fram.

Fig. (1) Elevation view of chopping machine.

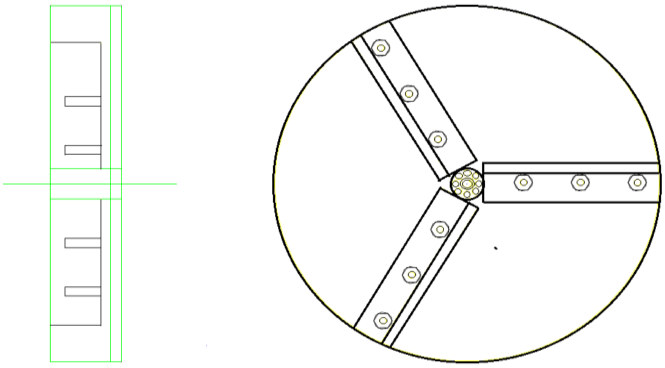


Fig. (2) Elevation and side view of the cutting disk of the chopping machine.

An Electrical drying oven was used to dry the samples of corn plant in order to calculate the corn moisture content. The drying oven has the following specifications:

Source of manufacture : Germany

Type : Binder ED-53

Oven capacity : 53 liter

Source of power : Electrical, 220 V, (2.6A) AC.

Operating power : 1.2 kW

Adjustment accuracy : ± 1° C

Rang of temperature : 5 – 240 ºC

The velocity of the rotating shaft was measured by means of a multi-range tachometer as shown in Fig (2). It gives the rotational terms of velocity in rpm.

Fig. (3). Multi-range hand tachometer for measuring the rotational speed.

Plant samples were dried at 105° C for 24 h using the electrical oven. The samples were weighted before and after drying and the corn moisture content (wet base) in (%) was determined using the following equation [17]:

$$\text{M.C.} = \frac{SB - SA}{SB} \times 100 \quad (1)$$

where M.C. – Corn moisture content (%) ;
SB – Sample weight before drying (g); and
SA – Sample weight after drying (g).

Cutting length of the final product is an important parameter to evaluate the performance of the cutting process. Where, the suitable cutting length (Lc) that can be used to produce compost and the forage is in the range of $0 < Lc < 50$ mm. Standard sieves that used for segregation a specific weight, (Sb) from the chopped production to several weight, having cutting length $0 < Lc < 50$ mm. Consequently, the cutting efficiency(η_c) in (%) can be calculated as follows:

$$\eta_c = \frac{\text{Sa}}{\text{Sb}} * 100 \quad (2)$$

where η_c – Cutting eficiency; S_b – Weight of the chopped production before segregation, (g); S_a – Weight of the chopped production after segregation of cutting length $0 < Lc < 50$ mm, (g).

The required power for chopping process was calculated using the following equation [18]:

$$EP = \frac{FC \times \rho_r \times L.C.V \times 427 \times \eta_m \times \eta_{th}}{3600 \times 75 \times 1.36} \quad (3)$$

where EP – Required power during the chopping process (kW); FC – Fuel consumption (L/h); ρ_r – Density of the fuel (0.85 kg/L); L.C.V – Lower calorific value of fuel (10000 kcal/kg); 427 – Thermo mechanical equivalent (kg.m/kcal); η_m – Mechanical efficiency of engine, 80%; η_{th} – Thermal efficiency of the engine, (considered to be about 40% for diesel engine).

Results and discussions.

The actual time increased with increasing rotational speed of knives. Increasing corn moisture content led to decreased the chopping time at each tested speed of knives.

Table (1) represents the values of the actual measured time in seconds at the three levels of corn moisture content for chopping machine.

Moisture content (%)	Actual chopping time (sec)				
	Rotational speed (rpm)				
	1200	1400	1600	1800	2000
54.11	10.09	9.67	9.4	7.32	5.97
	12.49	11.03	9.9	8.62	7.54
	14.16	13.16	11.92	11.17	10.15
64.19	9.92	9.31	7.91	6.57	5.53
	11.42	10.22	8.71	7.93	6.93
	13.68	12.28	10.66	10.44	8.53
73.45	9.59	8.49	6.73	5.86	3.72
	10.94	9.89	8.69	7.33	6.39
	13.44	10.66	9.89	9.08	8.37

Table (1): Chopping time at different levels of rotational speed of knives and three levels of corn moisture.

The fuel consumption increased with increasing the rotational speed of knives. Increasing the corn moisture content increased the required fuel at all levels of the knives rotational speed.

Table (2) represents the average values of fuel consumption for the different studied treatments.

Moisture content (%)	Fuel consumption (lit/h)				
	Rotational speed (rpm)				
	1200	1400	1600	1800	2000
54.11	1.75	2.00	2.40	2.92	4.02
	2.40	3.02	3.40	4.00	5.00
	2.50	3.24	3.84	4.60	5.20
64.19	1.90	2.15	2.73	3.51	4.34
	2.50	3.10	3.71	4.31	5.10
	2.74	3.50	4.15	4.45	5.50
73.45	2.1	2.52	3.30	3.80	4.70
	2.53	3.10	4.02	4.62	5.40
	2.72	3.42	4.33	4.90	5.70

Table (2): Fuel consumption in (lit/h) at different levels of rotational speed of knives at the three levels of corn moisture content.

The ratio between weight of the cutted pieces, up to 5 cm length, to the total feeding quantity is considered the cutting efficiency. Generally, increasing the rotational speed of knives led to increase the cutting efficiency at each level of moisture content of corn.

Table (3): Chopping efficiency at different levels of rotational speed of knives and three levels of corn moisture content.

Moisture content (%)	**Cutting efficiency (%)**				
	Rotational speed (rpm)				
	1200	**1400**	**1600**	**1800**	**2000**
54.11	91.60	92.58	93.43	94.33	96.96
	88.90	90.48	92.10	93.28	95.72
	87.00	89.51	90.71	92.11	94.24
64.19	89.45	91.13	92.55	93.63	94.47
	87.45	89.96	91.47	92.63	93.52
	86.73	88.52	90.30	91.58	92.92
73.45	88.13	90.73	91.92	93.31	94.33
	86.48	88.42	90.19	91.82	93.54
	84.92	86.00	88.18	90.32	92.12

The required power for the chopping process in (kw) was calculated according to the fuel consumption which measured during the chopping process. Normally, the required power increases with increase the rotational speed of knives. This was occurred at each level of corn moisture content. As for the corn moisture content before chopping, the required power increased with increasing the corn moisture content.

Table (4.): Required Power at different levels of rotational speed of knives and different levels of corn moisture content.

Moisture content (%)	Required power (kw)				
	Rotational speed (rpm)				
	1200	1400	1600	1800	2000
54.11	5.54	6.33	7.60	9.24	12.72
	7.60	9.56	10.75	12.70	15.81
	7.91	10.25	12.15	14.55	16.45
64.19	6.00	6.80	8.63	11.10	13.73
	7.91	9.81	11.73	13.63	16.13
	8.67	11.10	13.13	14.08	17.40
73.45	6.64	7.97	9.20	12.02	14.90
	8.00	9.81	12.72	14.61	17.10
	8.60	10.82	13.70	15.50	18.03

Conclusion.

The study showed that rotational speed of knives and moisture content has a significant effect on the process of chopping. The actual chopping time decreased with increasing the rotational speed of knives, increasing the corn moisture content. The required power for chopping processes increased with increasing both of rotational speed, corn moisture content and feeding quantity. Increasing corn moisture content led to decreased the chopping time at each tested speed of knives. At each feeding quantity, the copping time decreased as the corn moisture content increased. Increasing the corn moisture content increased the required fuel at all levels of the knives rotational speed. Generally, increasing the rotational speed of knives led to increase the cutting efficiency at each level of both feeding quantity and moisture content of corn before the chopping process. In addition to the cutting efficiency decreased when the corn moisture content increased before the chopping process.

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УДК 631.34