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Modification and evaluation a local thresher machine to suit chopping and grinding different crop residual

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Abstract : To achieve a safety healthy life for Egyptian farmers and to reduce environmental pollution and provide animal feed and provide organic fertilizer to the soil to improve the physical and chemical properties as well as increase its ability to retain water as long as Possible, especially with limitation of water resources in Egypt. Many agricultural machines most be devolved to be suitable for different areas. The current study sheds light on the development of domestic made machine to mince and chop agricultural residues such as corn and rice straw, which operates at the lowest possible energy. So the aim of the present work is to develop a local thresher machine, that combine shear and hammer mill theory. Developing was operated by the addition of two types of knives (knives sharp free + serrated discs) to the original knife existing already in the machine. This machine is evaluated in terms of production capacity and operating efficiency rotation of the machine on the three operating speeds (1200 - 1600 – 2000 rpm) and at different moisture content ratios (8 - 10 - 12%). The output evaluation was conducted on two different crops (corn stalk and rice straw). The experiments of this study were carried out in Privet Company meanwhile evaluating of production was done at the agriculture engineering institute, Gimaza research station. The output result showed that, minimum net power requirement obtained at 1200 rpm cutting drum speed for corn stalk were (3.1, 3.62 and 4.52kW) and rice straw were (3.34, 3.87 and 4.56 kW) at moisture contents (8, 10 and 12%). The maximum machine production for corn stalk was 0.72 ton/h at 2000 rpm cutting drum speed at 8% moisture content. It was 0.49 ton/h for rice straw at 2000 rpm cutting drum speed at 8% moisture content. The optimum cutting efficiency for corn stalk and rice straw were 95.8 % and 91.6%, respectively. It is achieved at 2000 rpm cutting drum speed and moisture content 8%. It can be commended that, throw out the addition of the disc mills and the other flail knives supports the process to the cutting force.

Key words: Modification, chopping machine, power requirement, knives shapes and agriculture resides

Introduction

Agricultural residues are considered to be one of the most critical problems facing the farmers. The first step towards solving this problem is to cut, crush and mill these lignocelluloses materials in order to be used as raw materials in several processes. **Giz**[1]reported that, Egypt generated 89.03 million tons of solid waste, including: agricultural waste, of 30 million tons. **El-Soaly**[2] said that, the environmental problems include all civilized societies and in Egypt, it became a big problem. The common problem is associated with crop residues accumulated in the field and their disposal, causing many problems to environmental balance.

Ibrahim[3] stated that, there are many problems associated with agricultural waste especially waste field for example: The nature of the chemical composition and the difficulty of decomposition due to higher content of cellulose materials, waste spread over large areas which requires taking into account the assembly and transport way, containing rats and harmful insects and cause bad environmental pollution when burned to humans, animals and field. **El-Fatih and A.E.Aref** [4] reported that, crop residues are considered among the most important materials in Egypt. There are many types and kinds of choppers in Egypt to assist in recycling the crop residues. The material is broken into large parts and accelerated to a velocity similar to the tip speed of the hammer. The accelerated particle impact against the screen and are further comminuted. The particles retained on the screen are under the action of hammer again **Hoque et al**[5].

Khattab et al[6] said that, the chopping process of agriculture crops is more complicated than in chopping of engineering materials (as steel, copper alloys, .etc.). This is due to that most of the engineering materials are homogeneous and isotropic, whereas the plants are non-homogeneous and non-isotropic materials. Each type of hammer mill has a range of rotary speeds for the main shaft to obtain high output and low energy consumption for each feed. If the rotary speed is too low, the grinding capacity is decreased and feed discharge is hampered, so the productivity is also reduced. If the rotary speed is too high, idle energy consumption is increased, as well as wear, tear and vibration, and the total energy consumed is higher **FAO**[7]. **Ghanem, G.H.A. and M.A. Basiouny**[8] reported that, the lowest rear clearance permissible is about 1cm distance and then the clearance ratios were calculated on this basis. The optimum operating conditions for chopping machine were determined regarding to percentage of un shredded green rice straw and chopping efficiency of rice straw.

Khattab et al [6] stated, the main important parameter of the cutting tools is the knife edge angle, and the main parameter is the chopping rotational speed. While, Omran, M.S.**9** indicated that, at higher cutting speeds the percentage of small cutting spices increases as a result of higher number of affecting chopping knives. On the other side, **El-Hanfy, E.H. and S.A. Shalby**[10] stated that, the average of cutting length decreased and the distribution percentage of short pieces increased by increasing and chopping speeds and overlapping between fixed and rotary knives. Also, **Womac Alvin R.**[11] mentioned that, disc mills produces very small parts if input feed is provided by knife mills or hammer mills. **El-Sayed, A.S.E.** [12] designed and constructed a prototype for picking, cutting and packaging the rice straw using sixteen knife disks which fixed on the main shaft. The knives disks were sharped to gradually stand the load of the cutting and forming three stages of clearance between knives.

Objective of the study

The main objective of this study is to develop a local thresher machine that combine shear and hammer mill theory.

Materials and Methods

The modified machine was fabricated at a private company and evaluated at the Agriculture Engineering Research Institute; Gimaza research station. It was used for crushing and milling different croup residues (corn stalk and rice straw). The field experiments were perforated during the season 2015 – 2016. The characteristics and structure of the machine parts as follows in Fig. 1; feeding inlet (1) and out let (2); feeding drums (3); wheels (4), control holder (5), chassis (6), flail knives (7), mill – chopping room (8), fixed knives (9), caver for pulleys (10), the PTO shaft (11), ball bearing (12) and hock connect (13). The distance between fixed notch knives is 5.5 cm.

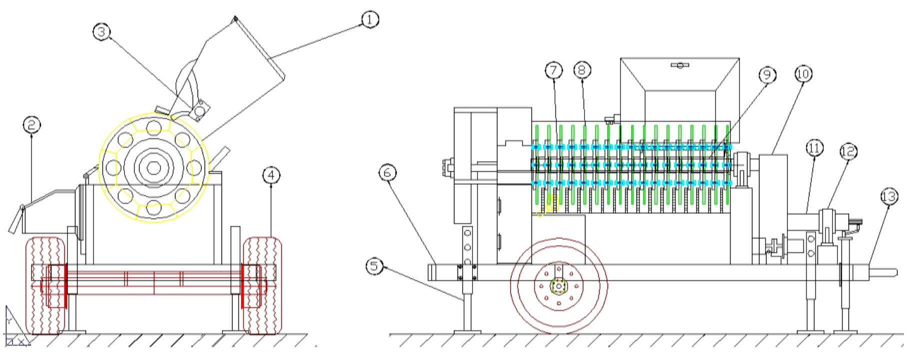

Fig. 1. The modified machine.

The residuals used in this work were obtained from private farms in Gharbia governorate and were stored in the workshop at room temperature of the agricultural engineering department until being used.

Fig. 2. The flail knives and saw disks.

The plane of the experimental work was executed through the following: two kinds of crops residues (corn stalk and rice straw), moisture content level: for corn stalk and rice straw were (8, 10 and 12%), cutting disc speeds were (1200, 1600 and 2000 rpm) and the distance between fixed knives is 10.5 where the new group of knives (flail knives + serrated disks) repeated eight times along the rotating drum. These goals achieved by adding a new design for the rotating drum in which arrangement between fixed, flail knives and saw disks as show in Fig. 2. This arrangement is in which knives have been replaced by others with sharp edge (12, 10, 9 inches) saw disk mills which have been set on the rotating drum.

The source of power was obtained from Belarus tractor 90 HP power for the chopping.

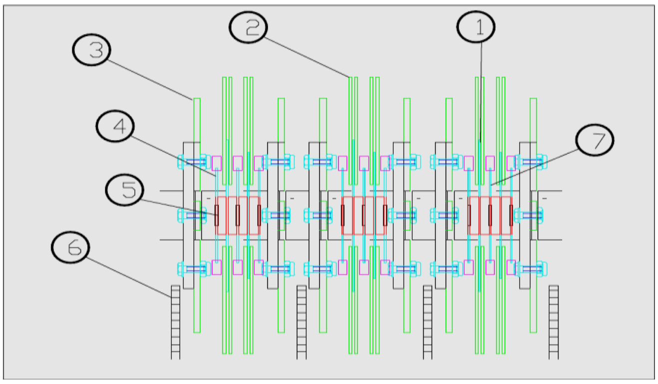

Fig. 3. The modified design of rotating drum.

Where: 1- the 12 inches saw disk, 2- the flail knife, 3- the fixed knife, 4- the 10 inches saw disk, 5- the spacers, 6- fixed bars and 7- the 8 inches saw disk.

Moisture content (M.C):

Plant samples were oven dried at 105° C for 24 h by using electrical oven. The samples were weighted before and after drying and the moisture content was determined by using the following equation: **AOAC** [13].

$$M.C. = \frac{SB - SA}{SB} \times 100 \quad \textbf{\% (Wet base)}$$

Where: SB = Sample weight before drying (g), SA = Sample weight after drying (g).

Machine productivity (Pm):

It was calculated by the following equation:

$$Pm = W/t \quad ton/h$$

Where: Pm = Machine productivity (ton/h), W = residuals weight of machine output (ton), t = Machine operating time (hr).

Cutting efficiency (ηc):

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

$$\eta c = Sa / Sb * 100$$

Where: Sb = Weight of the chopped production before segregation (g), Sa = Weight of the chopped production after segregation of cutting length $0 < Lc < 50$ mm (g).

Power requirement (EP):

The power was calculated by using the following equation **Embaby, A. T.** [14]

$$EP = \frac{FC \times \rho_r \times L.C.V \times 427 \times \eta_m \times \eta_{th}}{3600 \times 75 \times 1.36}, KW$$

Where: EP = Power requirements consumption during the chopping operation (kW), FC = Fuel consumption (L/h), ρr = 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), ηm = Mechanical efficiency of engine (80%), ηth = Thermal efficiency of the engine, (considered to be about 40% for diesel engine).

Energy consumption:

Energy requirements (kW.h/ton) = (power requirements, kW) / (machine productivity, ton/h).

After each chopping treatment, random sample (1kg each) was taken from chopped material to the laboratory; the total weight of samples and the mass of each product categories were weighed using digital scale with an accuracy of 0.01 g. The percent distribution of each fraction was determined by dividing the fraction's mass to the total mass of the output product.

Results

The discussion covered the obtained results under the following heads:

1. Chopping performance evaluation for corn stalks:

Performance evaluation of chopping machine used for corn stalk includes the following parameters.

Power requirements:

- **Total power requirements:**

The minimum value of total power requirement was 4.9 kW at 1200 rpm cutting speed, and 8 % moisture content while, the maximum value of total power requirement was 7.35 kW at 2000 rpm cutting speed and 12% moisture content. The total power requirements increased with increasing cutting drum speed.

For example, the total power requirements increased from 6.45 to 7.35 kW with increasing cutting speed from 1200 rpm to 2000 rpm at 12 % moisture content. Generally, the total power requirement depends on the cutting drum speed and the moisture content for corn stalk

The total power requirements increasing from 6.27 to 7.35 kW with increasing moisture content from 8% to 12% at 2000 rpm cutting speed. That is due to increase in moisture content, shear stress, compression stress and bending moment increase therefore total power requirement increases as showed at Fig. 4. Over all, the total power requirement increased with increase of moisture content and increase of cutting speed.

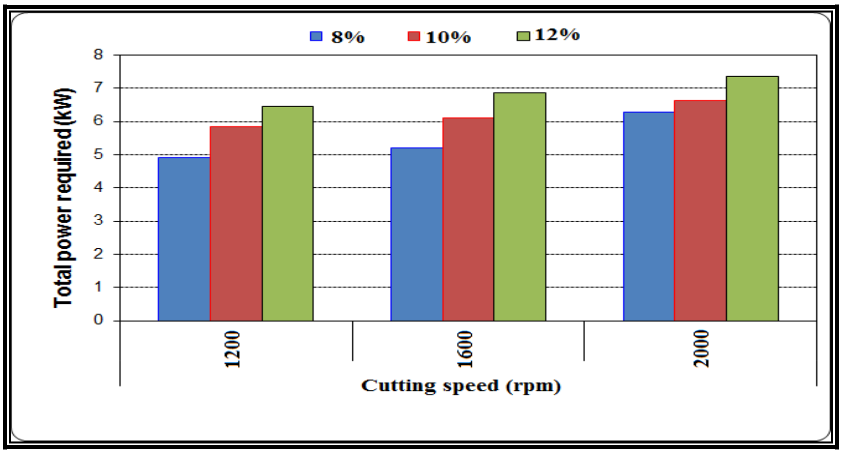

Fig. 4: The relationship between cutting drum speed and total power requirement at different levels of moisture content (8, 10 and 12%) for corn stalk

- **Net power requirements:**

The minimum value of net power requirement was 3.1 kW at 1200 rpm cutting speed and 8% moisture content while, the maximum value of net power requirement was 4.68 kW at 2000 rpm cutting speed and 12% moisture content. Over all, the net power requirement increased with increase of moisture content and increase of cutting speed.

Fig. 5. showed that, the net power requirements increased with increasing cutting drum speed, it increased from 4.52 to 4.68 kW with increasing cutting speed from 1200 rpm to 2000 rpm at 12% moisture content.

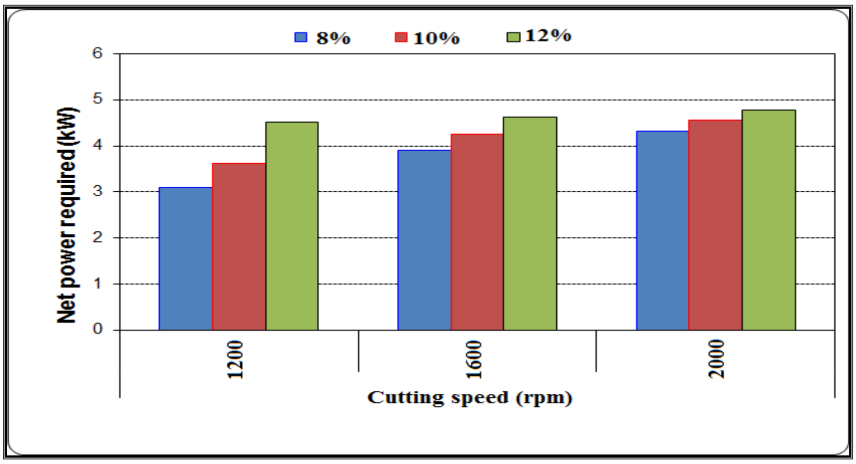

Fig. 5: The relationship between cutting drum speed and net power requirement at different levels of moisture content (8, 10 and 12%) for corn stalk.

By 2000 rpm, the net power requirements increased from 4.31 to 4.68 kW with increasing moisture content from 8% to 12%. Increasing the moisture content caused that shear stress, compression stress and bending moment increase therefore total power requirement increases.

Machine productivity:

The machine productivity was 0.63, 0.68 and 0.72 ton/h with increasing cutting speed from 1200, 1600 and 2000 rpm, respectively, at 8% moisture content. The minimum value of machine productivity was 0.42 ton/h at 1200 rpm cutting speed and 12% moisture content while, the maximum value of machine production was 0.72 ton/h at 2000 rpm cutting and 8% moisture content. The machine productions were affected by cutting drum speed as showed at Fig. 6.

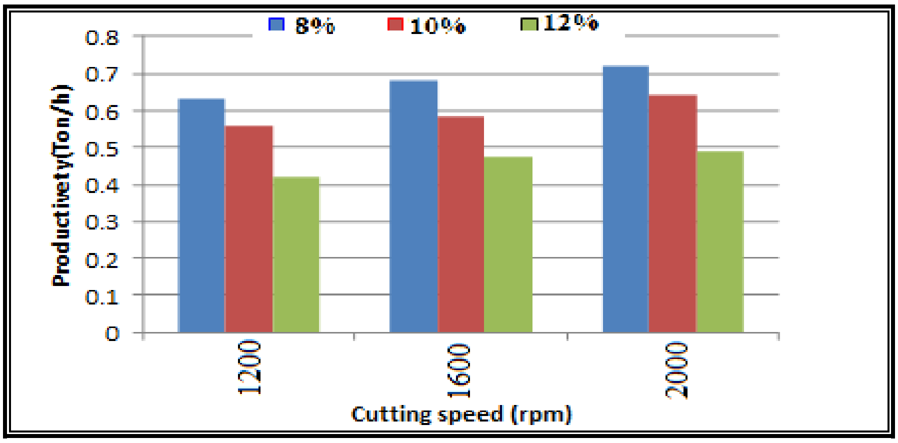

Fig. 6: The relationship between cutting drum speed and machine productivity at different levels of moisture content (8, 10 and 12%) for corn stalk.

Energy consumption:

The energy consumption was 12.8, 10.95, and 10.42 kW.h/t with increasing cutting drum speed from 1200, 1600 and 2000 rpm, respectively, at 12% moisture content. The minimum value of energy consumption was 7.0 kW.h/t at 2000 rpm cutting speed and 8% moisture content while, the maximum value of energy consumption was 12.8 kW.h/t at 1200 rpm cutting speed and 12% moisture content as showed at Fig. 7.0 The energy consumption decreased with increasing the cutting speed.

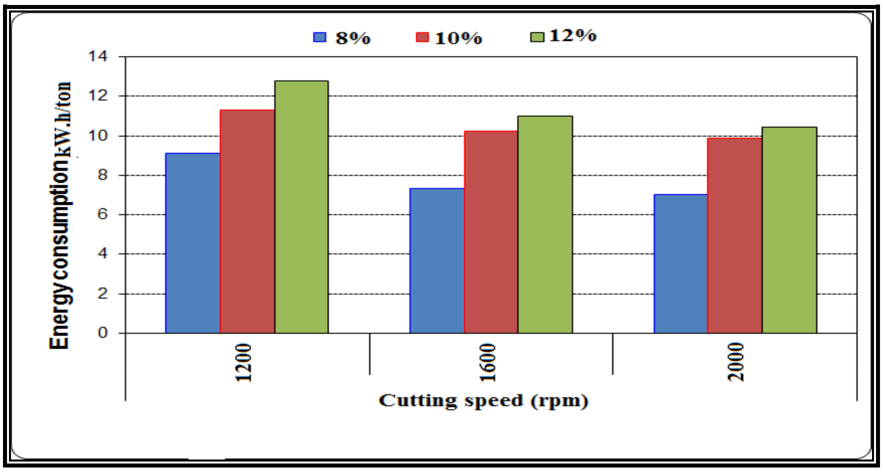

Fig. 7: The relationship between cutting drum speed and energy consumption at different levels of moisture content (8, 10 and 12%) for corn stalk.

Cutting efficiency:

The results showed that, with increasing the cutting drum speed from 1200 to 2000 rpm, the cutting efficiency increased from (91, 88 and 82.7 %) to (95.8, 92.8 and 86 %) at 8, 10 and 12 % moisture content, respectively.

Fig. 8. showed that, the cutting efficiency increased with decreasing M.C. and increasing cutting drum speed, that is due to an increase in the number of cuts per time unite and this increase the weight of the suitable cutting length. The cutting efficiency increased from 91 % to 95.8 % with increasing cutting speed from 1200 rpm to 2000 rpm at 8 % moisture content.

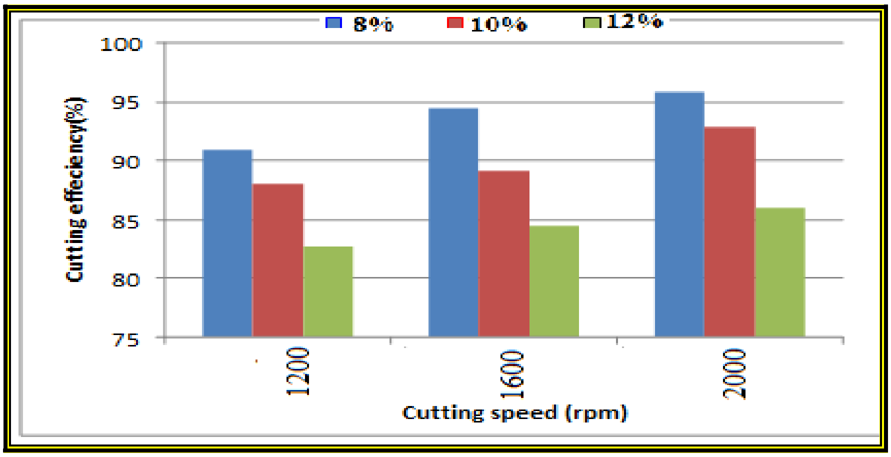

Fig. 8: The relationship between cutting drum speed and cutting efficiency at different levels of moisture content for corn stalk.

2. Chopping performance evaluation for rice straw.

Evaluation performance of chopping machine used for rice straw includes the following parameters.

Power requirements:

- Total power requirements:

The minimum value of total power requirement was 5.6 kW at 1200 rpm cutting speed, and 8 % moisture content while, the maximum value of total power requirement was 7.68 kW at 2000 rpm cutting speed and 12 % moisture content. Over all, the total power requirement increased with increase of moisture content and increase of cutting speed as show at Fig. 9. The total power requirements increased from 7.0 to 7.68 kW with increasing cutting speed from 1200 rpm to 2000 rpm at 12 % moisture content.

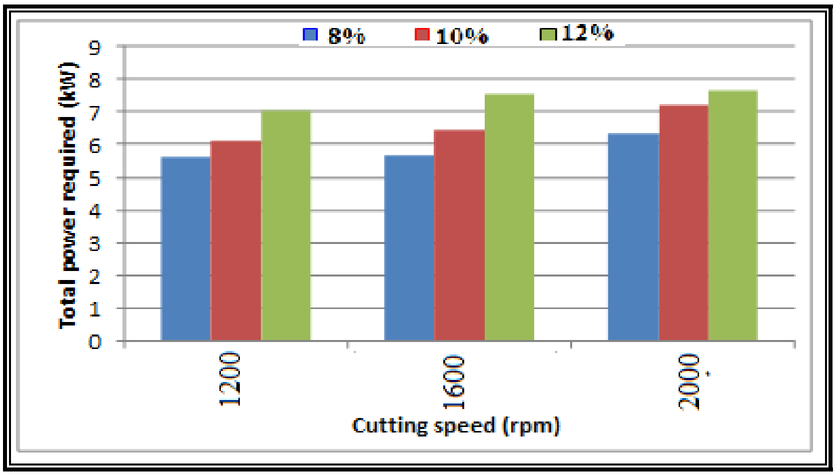

Fig. 9: The relationship between cutting drum speed and total power requirement at different levels of moisture content (8, 10 and 12%) for rice straw.

The total power requirements increasing from 6.35 to 7.68 kW with increasing moisture content from 8 % to12 % at 2000 rpm cutting speed.

- **Net power requirements:**

The minimum value of net power requirement was 3.34 kW at 1200 rpm cutting speed and 8 % moisture content while, the maximum value of net power requirement was 5.9 kW at 2000 rpm cutting speed and 12 % moisture content.

The net power requirements increased from 4.56 to 5.9 kW with increasing cutting speed from 1200 rpm to 2000 rpm at 12 % moisture content. The net power requirements increasing from 4.12 to 5.9 kW with increasing moisture content from 8 % to 12 % at 2000 rpm cutting speed. It increased with increasing moisture content as show at Fig. 10. The net power requirements between 8 % and 10 % M.C. were non obvious, in opposite to the net power requirement between 10 % and 12% M.C were clearly differences and this difference increased with increasing drum speed at 10 % and 12 %; it is due to cellulous materials in the rice straw because its chopping resistance increased with increasing the M.C.

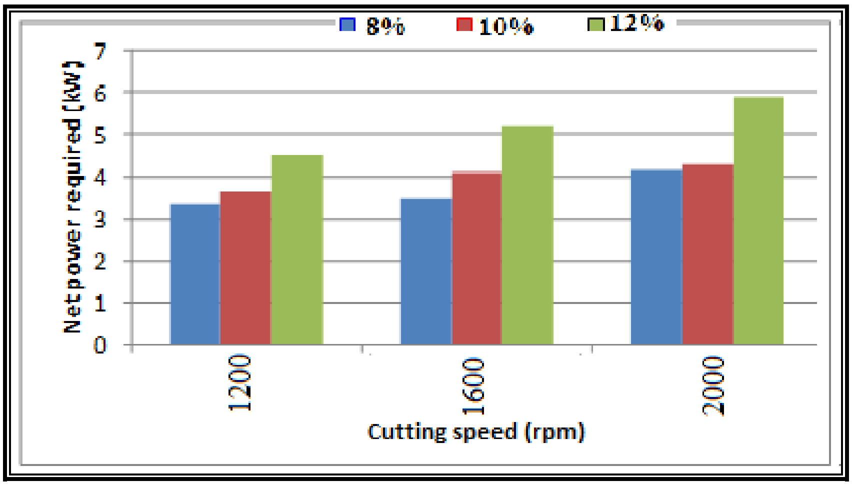

Fig. 10: The relationship between cutting drum speed and net power requirement at different levels of moisture content (8, 10 and 12%) for rice straw.

Machine productivity:

The machine productivity increased with increasing the cutting drum speed. The machine production was 0.412, 0.434 and 0.49 ton/h with increasing cutting speed from 1200, 1600 and 2000 rpm, respectively, at 8 % moisture content. The minimum value of machine productivity was 0.315 ton/h at 1200 rpm cutting speed and 12 % moisture content while, the maximum value of machine production was 0.49 ton/h at 2000 rpm cutting and 8% moisture content as show at Fig. 11.

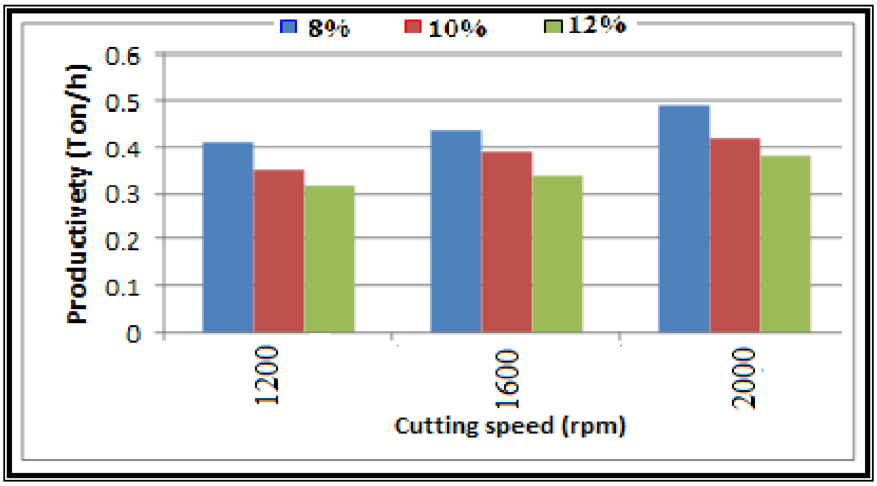

Fig. 11: The relationship between cutting drum speed and machine productivity at different levels of moisture content (8, 10 and 12%) for rice straw.

Energy consumption:

The energy consumption was 24.5, 22.1, and 21.8 kW.h/t with increasing cutting drum speed from 1200, 1600 and 2000 rpm, respectively, at 12 % moisture content. The minimum value of energy consumption 15.4 kW.h/t was at 2000 rpm cutting speed and 8 % moisture content. The maximum value of energy consumption was 24.5 kW.h/t at 1200 rpm cutting speed and 12 % moisture content. The Energy consumption decreased with increasing the cutting speed Fig. 12.

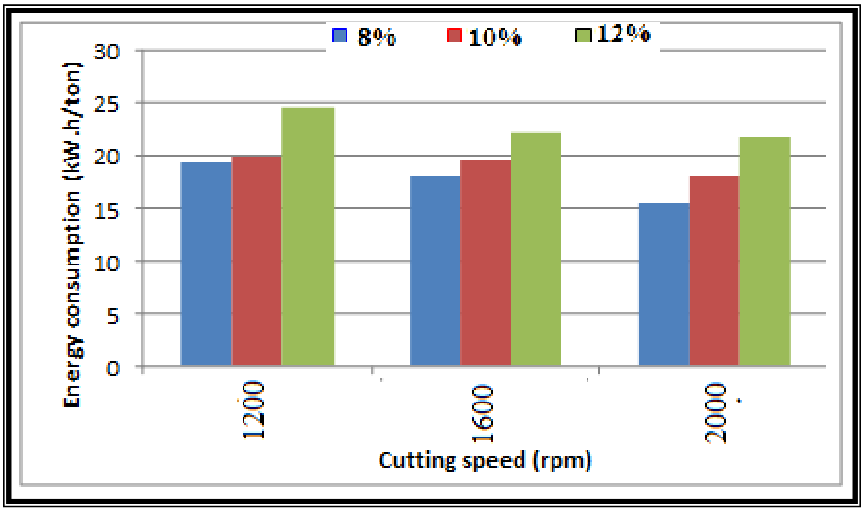

Fig. 12: The relationship between cutting drum speed and energy consumption at different levels of moisture content (8, 10 and 12%) for rice straw.

Cutting efficiency:

The cutting efficiency increased with increasing cutting drum speed and decreasing moisture content .The results showed that, with increasing the cutting drum speed from 1200 to 2000 rpm, the cutting efficiency increased from (87, 82.9 and 82.4 %) to (91.6, 85.5 and 84.9 %) at 8, 10 and 12 % moisture content, respectively.

The cutting efficiency increased from 87 % to 91.6 % with increasing cutting speed from 1200 rpm to 2000 rpm at 8 % moisture content as show at Fig. 13. The cutting efficiency difference between 8 % and other M.C. (10 % and 12 %) was very clearly at each drum speeds. On the other hand the cutting efficiency between 10 % and 12 % M.C. was very limited this represented that the best cutting efficiency was achieved at 8 % for rice straw by all drum speeds.

The cutting efficiency was very affected with moisture content especially between 8% and 10 %, on another hand the cutting efficiency was very near at 10 % and 12 %.

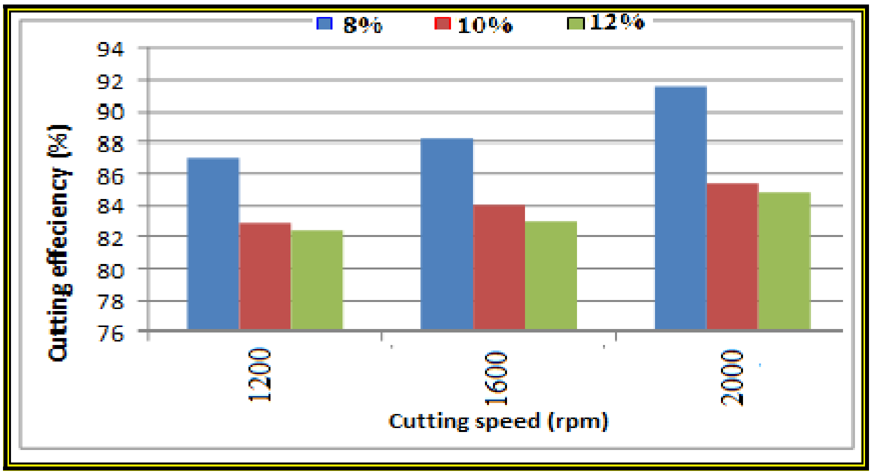

Fig. 13: The relationship between cutting drum speed and cutting efficiency at different levels of moisture content for rice straw.

Conclusion

From the above mentioned study, it can recommend the following points:

- Using the modified disk mill and flail knives decreased the energy requirement for chopping and increased fine degree of the chopped materials and solve the clogging problem.

- In the future research, there will be more studies for put double or third axes to be suitable for chopping more hard agricultural residues.

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