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QUALIFYING OF THE RICE STRAW CHOPPING UNIT

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ABSTRACT

The aims of this research has been carried out to qualifying a chopping unit for rice straw as a suitable length for livestock feed. The cutting unit was qualified to cut the straw. The qualifying unit performance was tested and evaluated in 2011-2012 seasons in Agric. Eng. Dept., Mansoura Univ. at four levels of cutting drum rotation speed of 2.00, 2.84, 3.64, 4.46 m.sec^{-1} with three levels of cutter drums interference of 10, 20 and 30 mm and three levels of cutting discs span of 15, 25 and 50 mm. The data were determine the effect of the above variables on average chopped straw length, straw chopped factor percentage and power requirements. The results indicated that the highest value straw cutting factor percentage were 99.60 % obtained at chopped unit rotation speed of 4.46 m.sec^{-1} and the cutter drums interference was adjusted at 10 mm when the cutting discs span was 25 mm. At these parameter the cutting straw length was about 24.9 mm and the power requirements was about 44.03 kW.

INTRODUCTION

Rice crop is the second importance cereal crop in Egypt, the grown area was about 1,6 million feddan which was produced about 4.8 million Mg grain. Whilst, growing rice involve many environmental problems concern with burning crop residues. **El-Dorghamy (2010)** signed that peak air pollution episodes known as *black clouds* are mainly attributed to upwind open burning of biomass (rice straw) among other wastes. **AWRU (2005)** estimated amount of agricultural waste in Egypt ranges from 30 to 35 million Mg. It added that, some of the agricultural waste is used as animal fodder, and other waste is used as fuel in indoor primitive ovens that causes health problems and damage to the environment. The rest is burned in the field such as rice straw, causing local and regional air pollution problems. **El-Berry et al. (2001)** reported that the quantity of crop residue in Egypt reached about 18.7-25 million Mg.year^{-1} and the national income might

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be increased by about 1.6 billion LE.year^{-1}, if we try to recycle it. Feeding animals with the form of cut straw into small pieces has many advantages especially in the missing quantity. Due to containing the hay a high percentage of crude fiber and special material like lignin and kyoten, too the digest will be decreased unless following the mechanical and chemical ways. To improve the nutritional value of straw from cutting hay into small pieces so that the juices of the digestive can be easily in the analysis of straw and thus improve digestibility. **Nader and Ropinson (2010)** explain that rice straw has great potential for use in rations for dairy replacement heifers, beef cattle, ...etc. Rice straw can supply them with a lower-cost forage that stimulates rumen development and provides bulk that limits total feed intake. www.PEPlus.com conducted that one of the best ways to deal with yard waste is to return it to your land. Grinding up your material into wood chips or finely shredding it so that it can be composted will enhance the health of your yard and allow you to skip the hassle of burning or landfill disposal. **Namikawa (1997)** recommended that the cutting speed must range between 15 to 30 m.sec^{-1} for the suitable hay shredding. He also mentioned that the speeds over than the optimum speed range caused a rapid increasing of specific energy recommended that chopping farm residues in pieces less than 30 mm improves its efficiency when used in feeding livestock. **Khadr et al. (1997)** studied the interaction effect between different speeds of cutter head and number of knives for cutting some field crop residues. He found that the cutting length decreased by increasing knives number and cutter head drum speed, while increasing cutter head knives decreased the power consumption. Meanwhile increasing cutter head drum speed causes an increase in the horsepower consumed. **Mohamed et al. (2001)** developed and evaluated a rice straw chopper. They results indicated that the productivity of the developed machines was 0.95 Mg.h^{-1} at 2000 rpm rotor speed and the cutting lengths of (10 - 90 mm) reached 95.25% from the total amount of cutting residue. **El-Iraqi and El Khawaga (2003)** designed a cutting machine for rice straw and maize stalks. It was operated at five cutting speeds ranged from 6.48 to 10.09 m.s^{-1}, three clearness between knives of 1.5, 3 and 4.5 mm and three feeding rates of 0.257, 0.514 and 0.771 Mg.h^{-1}. They results indicated that the maximum percentages in cutting length less than 5 cm of 87.80 and 92% were obtained for rice straw and corn stalks residues respectively, at cutting speed of 10.09 $m.s^{-1}$, feeding rate of 0.771 $Mg.h^{-1}$ and knife clearance of 1.5 mm. The energy consumed was 6.36 and 6.17 $kW.h.Mg^{-1}$ at the same previous parameters for rice straw and corn stalks, respectively. **Imbabi (2003)** tested the performance of a cutting machine for crop residues. The results showed that the highest values of both cut length and machine productivity were obtained at feeding drum speed of 300 rpm and cutting drum speed of 1500 rpm. The lowest costs were 12.97 $LE.Mg^{-1}$ with feeding rate of 1.873 $Mg.h^{-1}$.

The aims of this research has been carried out to qualifying a chopping unit to suit rice straw and determine the optimum variable parameters suitable length for livestock feed.

MATERIALS AND METHODS

The research carried out in Agric. Eng. Dept. Mansoura Univ. in 2011-2012 seasons to evaluate the performance of qualifying chopping unit. The qualifying chopping unit as shown in Figs. 1 and 2 consists of two cutter drums with round disc knifes. Two inside different cutter drums have the chopping action for the picked straw after feeding to the unit which do the work by organized steps by first caught the mirrored straw to the top drum then press the straw between the cutting edges of the top and down cutter drums, which rotates in reverse to them selves. The cutter drums; the top and the bottom one every one has its own. The qualifying is controlling the distance between the cutting discs using the different collars width and increase the cutting disc number, also added the U shape knives to modify the cutting straw length to reach 15 mm (Fig. 2).

The source of power supplied with PTO using 47.81 W (65 hp) tractor.

The rice straw properties after harvesting were measured. It is moisture content is about 25±3% and the average length is about 550 mm.

The qualifying unit performance was tested and evaluated at four levels of cutting drum rotation speed of 2.00, 2.84, 3.64, 4.46 $m.sec^{-1}$ with three levels of cutter drums interference of 10, 20 and 30 mm and three levels of cutting discs span of 15, 25 and 50 mm. The straw flow rate is adjusted at 0.938 $Mg.h^{-1}$ and the qualified unit forward speed of 0.784 $km.h^{-1}$. The tests were replicated three times for each treatments of cutting unit. The data were statistically analyzed to determine the effect of the above variables on average chopped straw length, straw chopped factor percentage and power requirements.

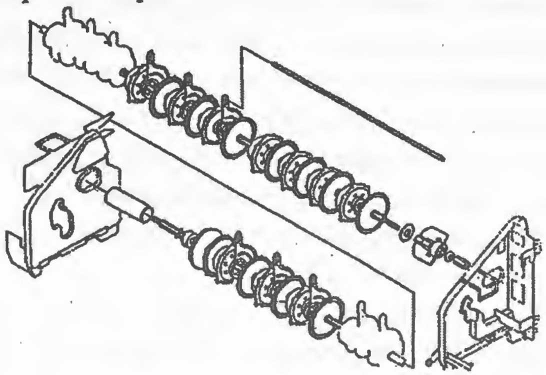

Fig. 1: The qualified chopping unit schematic diagram.

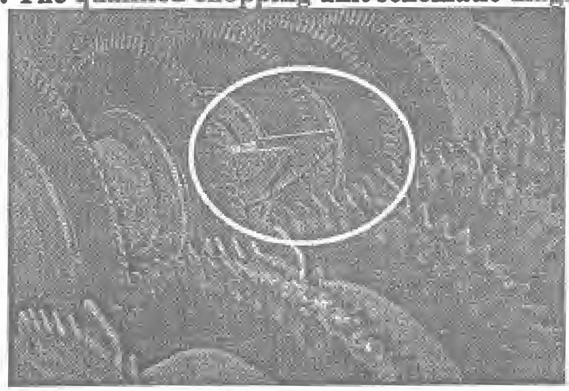

Fig.2: The cutting unit.

1- The average chopped straw length (AS_l, mm) was measured by ruler at every treatment.

2- The straw chopped factor percentage (C_E, %) was calculated as follows:

$$C_E = \frac{AS_L}{C_s} \times 100 \ , \quad \%$$

Where: AS_L: average chopped straw length in the same category, mm

C_S : cutting discs span, mm.

3- Power requirements (Pr) was calculated as follows: according to **(Barger et al., 1963)** ,

$$Pr = \left(\frac{F_u \times \rho_f \times C.V}{3600}\right) \times \left(\frac{427 \times \eta_{th} \times \eta_m}{75 \times 1.36 \times FC}\right) \quad , \text{ kW}$$

where:

F_u : fuel consumption rate, $L.h^{-1}$;

$?_f$: density of fuel, $kg.L^{-1}$, (for diesel = 0.85 $kg.L^{-1}$);

C.V : calorific value of fuel, $kcal.kg^{-1}$;

427 : thermal-mechanical equivalent, $kg.m.kcal^{-1}$;

$?_{th}$: thermal efficiency of the engine, assumed 40 % for diesel engine;

$?_m$: mechanical efficiency to engine, assumed 80 % for diesel engine;

Fc : actual field capacity, $Fed.h^{-1}$;

RUSULTS AND DISCUSSION

Factors affecting the average chopped straw length

The relationships between the qualifying unit rotation speed and the average of chopped straw length at the different cutting discs span and the cutter drums interference are illustrated in Fig. (3). As matter of fact, there are a direct relationship between the rotation speed and the average straw length. From Fig. (3-A) it can be seen that by increasing the rotation speed the average straw length increases at each of different cutting discs span. As shown in Fig. (3-A) the best cutting results indicated that the highest values of the average cutting straw length were about 14.7, 24.8 and 49.1 mm respectively at cutting discs span of 15, 25 and 50 mm using the rotation speed of 4.46 $m.sec^{-1}$, while the corresponding lowest values are 14.2, 23.6 and 47.3 mm respectively using the rotation speed of 2.00 $m.sec^{-1}$.

On the other sides, Fig. (3-B) shows that the direct proportional relationship between the rotation speed and the average of chopped straw length at the different cutter drums interference. The figure clear that the average of chopping straw length increase from 28.34 to 29.99 mm by increasing the rotation speed from 2.00 to 4.46 $m.sec^{-1}$. Meanwhile, the average of chopping straw length increase of 28.88, 28.94 and 29.02 mm respectively at cutter drums interference of 10, 20 and 30 mm. These results clear that the high variables effect on the chopped straw length is the cutting disc span followed by rotation speed, finally the cutter drums interference. These results agreement with Mohamed et al. (2001) and El-Iraqi and El Khawaga (2003).

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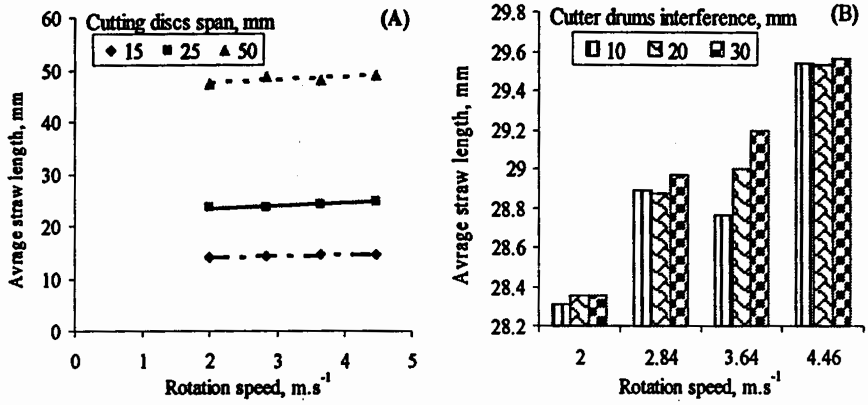

Fig. 3: Effect of the cutting unit rotation speed and the average straw length.

The statistically analysis of SAS shows that there is high significance differences between the treatments of rotation speed and the average cutting straw length at the different cutting discs span and the cutter drums interference. Also the total interaction between different treatments show high significant effect with (Pr = 0.0001) and (C.V=0.336). A multiple regression analysis applied to relate the change in rotation speed and the average of chopped straw length at the different cutting discs span and the cutter drums interference for all treatments. The obtained regression equation was in the form of:

$$SL = 0.0762\ CR + 0.9578\ CS - 0.0014\ CI$$

Where: SL: average chopped straw length, mm

CR : rotation speed, m.sec^{-1}

CS: cutting discs span, mm

CI : cutter drums interference, mm

The analysis of variance for the data of the rotation speed and the average of chopped straw length at the different cutting discs span and the cutter drums interference indicated a highly significant differences for the treatments with ($R^2 = 0.9998$).

Factors affecting the straw chopped factor percentage

The relationships between the rotation speed and the straw chopped factor percentage at the different cutting discs span and the cutter drums interference are illustrated in Fig. (4). Therefore, there are a direct relationship between the rotation speed and the straw chopped factor percentage at the different cutting discs span and the cutter drums interference. Fig. (4-A) illustrate that by increasing the rotation speed from 2.00 to 4.46 $m.s^{-1}$ the straw chopped factor percentage increases from 94.42 to 98.51 %. Consequently, Fig. (4-A) shows the slightly differences about 0.283% in chopped straw length. Furthermore, from Fig. (4-B) it can be shows that the highest values of the straw chopped factor percentage were about 98.56, 98.41 and 98.56 % respectively obtained at cutter drum interference of 10, 20 and 30 mm when the rotation speed was 4.46 $m.sec^{-1}$. Consequently, the lowest values were 94.30, 94.46 and 94.50 % respectively at the above cutter drum interference and 2.00 $m.sec^{-1}$ rotation speed. These results may due to the increase of rotation speed effect of the speed of cutting the fiber materials as rice straw, while the effect of cutting discs span and the cutter drums interference are slightly compared with the rotation speed.

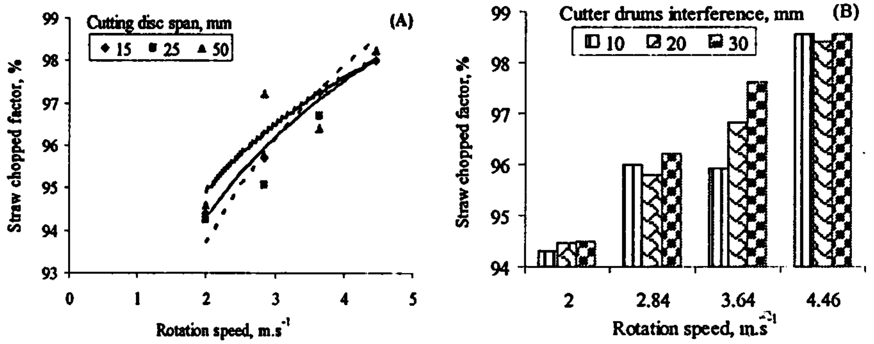

Fig. 4: Effect of the cutting unit rotation speed and the straw chopped factor percentage.

The statistically analysis of SAS shows that there is high significance differences between the treatments of rotation speed and the straw chopped factor percentage at the different the cutting discs span and the cutter drums interference. Also the total interaction between different treatments show high significant effect with (Pr = 0.0045) and (C.V=0.449).

A multiple regression analysis applied to relate the change in rotation speed and the straw chopped factor percentage at the different cutting discs span and the cutter drums interference for all treatments. The obtained regression equation was in the form of:

$$Se = 16.385\ CR + 0.5380\ CS + 1.1730\ CI$$

Where: Se : straw chopped factor percentage, %

The analysis of variance for the data of rotation speed and the straw chopped factor percentage at the different the cutting discs span and the cutter drums interference indicated a highly significant differences for the treatments with (R2 = 0.9627) .

The power requirements

The relationships between the rotation speed and the power requirements at the different cutting discs span and the cutter drums interference are illustrated in Fig. (5). Hence, there are a direct relationship between the rotation speed and the power requirements at the different cutting discs span and the cutter drums interference. As shown in Fig. (5-A) the results indicated that the values of the power requirements were about 42.61, 42.98, 43.75 and 44.29 kW respectively at 2.00, 2.84, 3.64 and 4.46 $m.s^{-1}$ which the power requirements were slightly differences of 0.51 kW at cutting disc span differences. Therefore, Fig. (5-B) shows the relationship between the power requirements and the rotation speed at different cutter drums interference. The figure clear that the power requirements increase from 42.58 to 44.27 kW by increasing the rotation speed from 2.00 to 4.46 $m.s^{-1}$. These logical results as the rotation speed the power requirements increased, then the effect both of cutting disc span and cutter drums interference can be neglected.

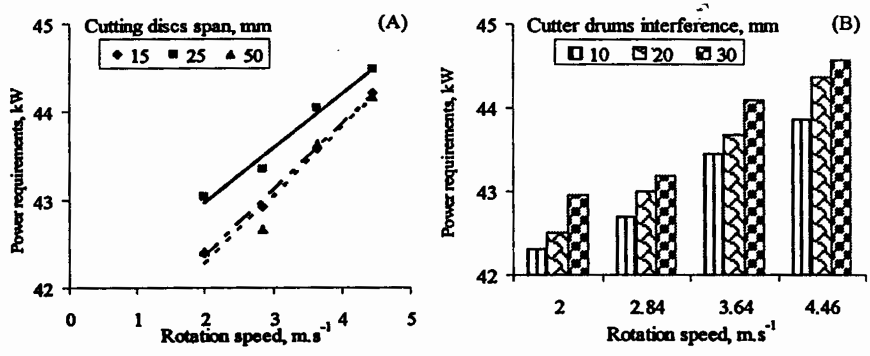

Fig. 5: Effect of the rotation speed on power requirements.

The statistically analysis of SAS shows that there is high significance differences between the treatments of the rotation speed and the power requirements at the different cutting discs span and cutter drums interference. Also the total interaction between different treatments show high significant effect with (Pr = 0.0001) and (C.V=0.084). A multiple regression analysis applied to relate the change in the rotation speed and the power requirements at the different cutting discs span and cutter drums interference for all treatments. The obtained regression equation was in the form of:

$$Pr = 7.3473\ CR + 0.2218\ CS + 0.5460\ CI$$

Where: Pr : power requirements, kW.

The analysis of variance for the data of rotation speed and the power requirements at the different cutting discs span and cutter drums interference indicated a highly significant differences for the treatments with ($R^2 = 0.9629$).

CONCLUSION

The conclusions of this paper are the highest value straw cutting factor percentage were 99.60 % obtained at chopped unit rotation speed of 4.46 $m.sec^{-1}$ and the cutter drums interference was adjusted at 10 mm when the cutting discs span was 25 mm. At these parameter the cutting straw length was about 24.9 mm and the power requirements was about 44.03 kW.

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الملخص العربى

تعديل وحدة تقطيع قش الأرز

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** ناهد خيري اسماعيل　　*أحمد شوقي السيد السيد

للمساهمة فى حل مشكلة التلوث البيئي الناجم عن حرق مخلفات قش الأرز وكذلك المساهمة في سد العجز في أعلاف الماشية عن طريق إنتاج الأعلاف غير التقليدية من مخلفات قش الأرز لتقليل استيراد الذرة الصفراء والأعلاف المركزة وتوفير العملة الصعبة خاصة بعد ارتفاع أسعار الأعلاف.

لذا يكمن هدف البحث فى تطوير وحدة لتقطيع قش الأرز إلي أطوال مناسبة لتغذية الحيوانات وتتكون هذه الوحدة من درفيلين متداخلين يحتويان علي سكاكين قرصية وللحصول على أطوال صغيرة ومختلفة من قش الأرز تم تعديل توزيع السكاكين وزيادة عددها عن طريق إضافة جلب مختلفة الأطوال بين السكاكين وكذلك تم إضافة سكين على شكل حرف U بين السكاكين. وقد تم الدراسة لتقييم الأداء الآلى للوحدة المعدلة تحت متغيرات:

١- أربعة سرعات دورانية لوحدة التقطيع (٢,٠٠, ٢,٨٤, ٣,٦٤, ٤,٤٦ م.ث-١).

٢- ثلاثة خلوصات لتداخل درفيلي التقطيع (١٠, ٢٠, ٣٠ مم).

٣- ثلاثة مسافات بين السكاكين وهي(١٥, ٢٥, ٥٠ مم).

وأظهرت النتائج أنه يمكن إستخدام الوحدة المعدلة للحصول على أعلى نسبة لمعامل القش المقطع (٩٨,٦٠%) عند سرعة دوران وحدة التقطيع ٤,٤٦ م.ث-١، والخلوص بين درفيلى التقطيع ١٠مم، ومسافة بين السكاكين ٢٥مم. وكان طول القش المقطوع والمتطلبات القدرة عند مستويات عوامل الدراسة السابقة حوالى ٢٤,٩مم، ٤٤,٠٣كيلووات على التوالى.

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