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Developing a Conical Drum for Chopping Palm Fronds

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ABSTRACT

The present study was carried out in Agric. Eng. Dept., faculty of Agric., Mansoura Univ. to develop a conical drum for chopping palm fronds and to evaluate the performance of the developed machine. The field experiments were conducted to determine the suitable operation parameters for cutting palm fronds to reach the part lengths suitable for the manufacture of animal feed (silage), compost, simple handicraft industries and renewable energy production. The results showed that increasing the cutting drum speed from 7.75 to 15.44 m/s reduced the cutting length from 6.8 to 3.6 mm and increased the power requirement about 42.8%. The machine productivity was around 262 and 241 palm fronds/h with 89.8 and 86% machine efficiency.

INTRODUCTION

Despite the important economic situation that Egypt occupies in the production of dates palm globally. Palm trees are one of the most important sources of horticultural residual in Egypt. Official data showed that the cultivated area with palm trees in 2014 amounted to 44037 ha (110092 faddans) i.e. about 17 million palm trees with an annual production of 1465030 tons (FAO, 2017).

Sharawy (2015) communicate that to utilization of palm fronts is used in some simple handicraft industries such as baskets and cages. The industry is not expensive and does not rely on machines or equipment. It also needs regular labor that can be trained on this craft. As the accumulation of these wastes lead to dehydration and arson in order to get rid of them, which leads to fires and the escalation of carbon dioxide gas at the expense of air oxygen, which helps to increase the proportion of air pollution.

There are many types of residual cutting machines according to the theory of precise cutting such as the flywheel-type cutter head and the cylinder-type cutter head. Kepner, *et al*. (1993) recorded that, flywheel-type cutter head usually have between 4 and 6 knives. Most cylinder-type cutter head have 6 knives and diameter of 380 to 460 mm or 9 knives and diameter of about 610 mm. With either type, some of the knives can be removed to increase the length of the cut. The remaining knives must be equally spaced to maintain cutter head balance.

Ismail and Ghazy (2016) evaluated a local wood chipper machine from operating parameter of drum chipper on wood chip removal rate, actual chip thickness, share plan angle, chip thickness ratio, chip reduction coefficient, size classification of wood chips and the machine productivity. They found that increasing each of cutting depth and cutting drum revolution increasing the wood chips productivity. Using local wood (Palm fronts) material, the wood chips productivity were 237.38; 261.12 and 284.86 kg/h at 5000; 5500 and 6000 rpm cutting drum revolution.

Ismail and Ghazy (2017) reported that the feeding rate and drum peripheral speed are considered the best main factors affecting machine productivity. They found that using cutting drum speed (17.11 m/s) and feeding material speed (0.68 m/s) the machine produced about (10 kg/h). The same machine production can be obtained with using same cutting drum speed with feeding material rate of (0.77 m/s) but the cutting pieces included a large amount of pieces with a big width.

Abo-Elasaad (2016) reported that the cutting-length percentage of residual crop for small-size categories less than 8 cm. increased by increasing cutting drum speed. Meanwhile, the cutting-length percentage of residual crop for large-size categories longer than 8 cm. decreased. He found that increasing the cutting drum speed from 750 to 1260 rpm increase the small-size categories less than 8 cm. from 47 to 69% and decrease large-size categories longer than 8 cm. from 53 to 31%.

The objective of this study is to develop a conical drum for threshing machine to become suitable for cutting the palm fronts.

MATERIALS AND METHODS

The experiments of this study were carried out in Agriculture Engineering Department, Faculty of Agriculture, Mansoura University. Two types of palm fronds {at moisture contents 14% (Mois1) and 27% (Mois2)} were used in this study, the first type is palm fronds from trees older than 20 years, while the second type is palm fronts from trees five years old from Zaghloul kind. The cutting drum speed, which used under this study were R1 (7.75 m/s) and R2 (15.44 m/s).

Developed conical cutting drum:

The experimental machine was modified and evaluated at the Agricultural Engineering Department, Faculty of Agricultural, Mansoura University. The developed conical cutting drum was combined into a conventional threshing machine and a feeding mechanism was added to control the machine feed rate as shown in Fig. 1.

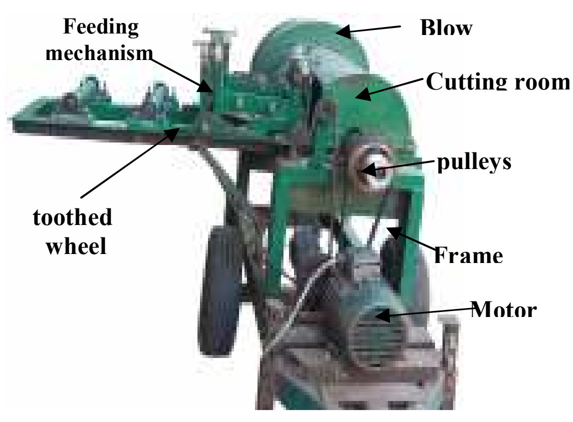

Fig. 1. The experimental machine

The developed conical cutting drum was consisted of three Hexagonal flanges with (32,18 and 12 cm) diameters. They were fixed on the axial main shaft at distance between flanges 39 and 17cm, respectively (Fig. 2). The smallest one is considered central point to moved knives and the other flanges equipped with channel to control of cutting tilt-angle.

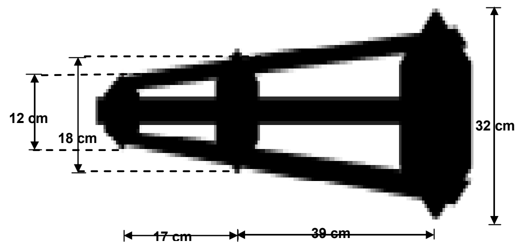

Fig. 2: Sketch of cutting drum

Moisture content:

Palm fronds moisture content was measured using Pin-type Moisture Meters (Fig. 3), US- made, Model: J- LITE, Power source: National battery and Range of 6 to 30%.

Fig. 3. Photograph of Pin-type Moisture Meters

Cutting speed:

Cutting drum speed was measured by using digital contact tachometer (Fig. 4) The tachometer specifications are: Source of manufacture: Taiwan, Model: 461895, Range of : 0.5 to 999,99 rpm and accuracy : 0.05 rpm.

Fig. 4. Photograph of Hand tachometer

Power requirement:

The machine power requirement (P) was calculated according to Kurt (1979) using the equation form:

$$\textbf{Power, kW} = \sqrt{3} \times I \times V \times \eta \times \cos\theta / 1000 \quad (1)$$

Where:

P : Power requirement for the cutting machine, kW;
I : Line current strength in amperes;
V : Potential difference (Voltage) being equal to 380 V;
Cos θ : Power factor (being equal to 0.85);
$\sqrt{3}$: Coefficient current three phase (being equal 1.73) and
η : Mechanical efficiency assumed, (95 %).

A clamp meter was used for measuring current intensity and voltage. A clamp meter is shown in Fig. 5. Source of manufacture: Japan, Type: Super clamp meter 700k 600v~Ac 50 Hz, Power source: National battery, Accuracy: 0.5 Ampere and Measurements: A.c. Amperage, A.c. Voltage, Resistance.

Fig. 5. Photograph of clamp meter

Machine productivity:

Machine productivity was calculated by using the following relation:

$$M_p = F_S / L \qquad (2)$$

Where:

M_p: Machine productivity(number palm fronds /h).
F_S : Feeding speed (m/h).
L : Average length of one palm fronds (m).

Machine efficiency:

Machine productivity was calculated by using the following relation:

$$M_{eff} = (M_{p.th} / M_{p.p}) \times 100 \qquad (3)$$

Where:

M_{eff} : Machine efficiency (%)
$M_{p.th}$: Theoretically machine productivity (number palm fronds /h).
$M_{p.p}$: practically machine productivity (number palm fronds /h).

RESULTS AND DISCUSSION

Cutting length:

The cutting length depends on the feeding speed and the peripheral speed of the cutting knife. the obtained results recorded a feeding rate about 23.58 and 22.96 cm/sec for palm fronds with moisture content (27 and 14 %) respectively. While theoretically study recorded 30.64 cm/sec. From above results, it may be recorded that the theoretical cutting length is 4.48 and 4.64 mm at the cutting drum speed (R_1), and 2.25, 2.32 mm at the cutting drum speed (R_2) for type1 and type2 palm fronds, respectively.

The obtained results showed an increase in the length of the actual pieces attributed to the theoretical length by (59.6 and 59.9%) at the cutting speed (R_1) and (52 and 55.6%) at the cutting speed (R_2) for type1 and type2 palm fronts, respectively, as shown in Fig. 6. This may be due to set the palm fronts under the force of the feeding device during being held in the slide knife wing during the rotation of the cutting drum, resulting in the payment of the palm fronds longer than the theoretical distance, resulting in an increase in the length of the cutting parts.

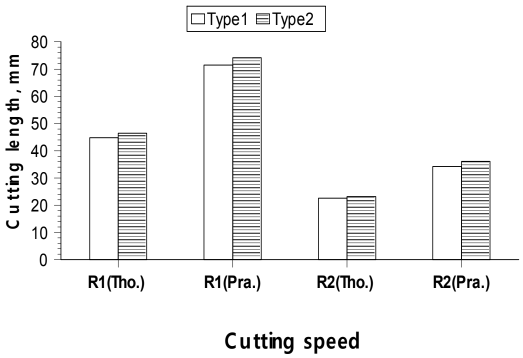

Fig. 6. Effect of cutting speed on theoretical and actual cutting length at different types of palm fronds with individual feeding.

Power requirement:

The power requirement to operate the cutting palm fronds machine depends on a number of factors, the most important of which are the cutting speed, cutting knife tilt-angle and the moisture contents of palm fronts.

The results show in Fig. (7) that by decreasing palm fronds moisture content the power requirement decreased. At cutting speed (R_1), decreasing the palm fronds moisture content from 27 to 14% decreased the power requirement about 17.12%. Whereas, at cutting speed (R_2), decreased the power requirement about 13.00%.

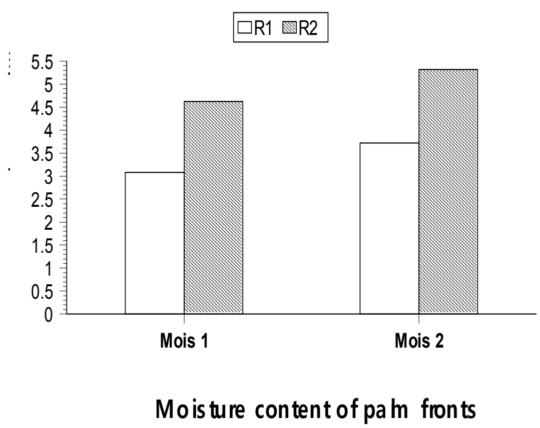

Fig. 7. Effect of palm fronds moisture contents on power requirement at different cutting speed with individual feeding.

The results show that by increasing cutting knife tilt-angle the power requirement decreased. At (Mois1) moisture content, increasing cutting knife tilt-angle from zero to 5 and 10 degree the power requirement decreased about 12.8 and 25.6% with cutting speed (R_1) and about 8 and 15% with cutting speed (R_2), respectively.

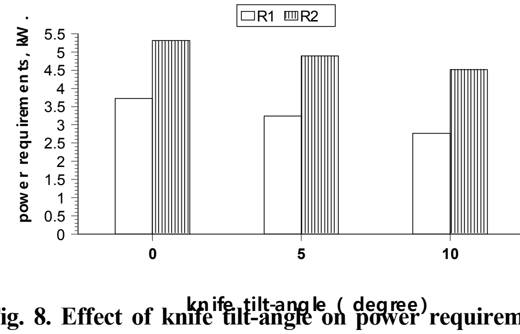

Fig. 8. Effect of knife tilt-angle on power requirement at (27% moisture content) and different cutting speed with individual feeding.

At (Mois2) moisture content, increasing cutting knife tilt-angle from zero to 5 and 10 degree the power requirement decreased about 11.2 and 20.6% with cutting speed (R_1) and about 6.1 and 11.2% with cutting speed (R_2), respectively.

Fig. 9. Effect of knife tilt-angle on power requirement at (14% moisture content)and different cutting speed with individual feeding.

Machine productivity and efficiency:

Figure (10) shows the effect of palm fronds moisture content on machine productivity, where the machine productivity was theoretically estimated at 584 and 562 palm fronds/h with the use of the (type1) of palm fronds and 456.6 and 444.4 palm fronds/h with the use of the (type2) at moisture content (Mois1 and Mois2), respectively. While the actual productivity of the machine was 512.6 and 470.2 palm fronds/h when using the type1 of palm fronds, as well as 394.2 and 372.5 palm fronds/h with the use of the type2 of palm fronds at moisture content (Mois1 and Mois2), respectively.

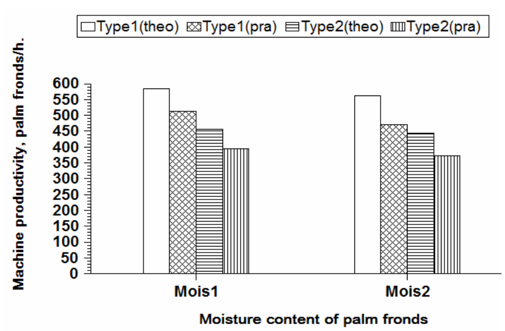

Fig. 10. Effect of palm fronds moisture contents on theoretical and actual machine productivity at different types of palm fronds with double feeding.

The results obtained showed that the efficiency of the machine with individual feeding was 89.8% and 86% at the moisture content (Mois1 and Mois 2), respectively. This is due to the regularity of the feeding rate in the case of moisture content (Mois 1) compared to the rate of feeding rate in the case of (Mois 2). While the machine efficiency with double feeding decreased by 2.1 and 2.3% compared to the individual feeding and often the reason for the difference in thickness of the palms, resulting in a difference in the speed of feeding between the palms, which increases the time required to cut the palm fronts in the double state resulting in a decrease in machine operating efficiency.

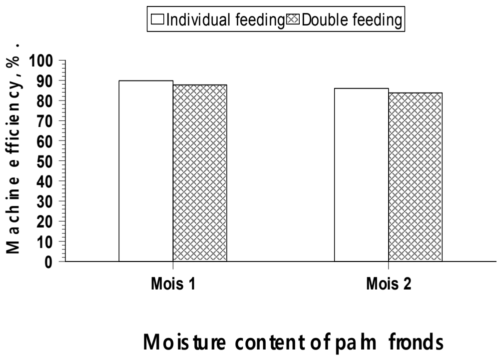

Fig. 11. Effect of palm fronds moisture contents (at type1) with individual and double feeding on machine efficiency .

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تطوير درفيل مخروطي لتقطيع سعف النخيل

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تنتشر زراعة نخيل البلح في معظم محافظات جمهورية مصر العربية وتبلغ المساحة المزرعة حوالي 44037 هكتار (110092 ألف فدان)، تنتشر بها ما يقرب من 17 مليون نخلة، تنتج سنوياً 1,465,030 طن من التمور (الفاو 2017). تبلغ كمية المخلفات (سعف النخيل) الناتجة سنوياً ما يقرب من 1,7 مليون طن، والتي يتم التخلص من معظمها بالحرق وما يترتب عليه من تلوث للبيئة. وحديثاً يتم الاتجاه للاستفادة من سعف النخيل في صناعة أغذية الحيوانات (علائق الغير تقليدية)، صناعة الأخشاب، إنتاج الطاقة الجديدة والمتجددة بالإضافة إلى تصنيع الأسمدة العضوية (الكومبوست). لذا تهدف هذه الدراسة لتطوير درفيل مخروطي لآلة الدراس لتصبح مناسبة لتقطيع سعف النخيل. و قد تم التوصل إلى مجموعة من النتائج يمكن توضيحها فيما يلي: - زيادة سرعة دوران درفيل القطع من 7,75 إلى 15,44 م/ ث أدى إلى تقليل طول القطع من 6,8 إلى 3,6 مم. - زيادة سرعة دوران درفيل القطع من 7,75 إلى 15,44 م/ ث أدى إلى زيادة القدرة اللازمة للقطع بمقدار 42,8%.- تتراوح إنتاجية الآلة ما بين 241- 262 جريدة/ ساعة بكفاءة تشغيل ما بين 86 - 89,6%. وبناءا على ما سبق فإن درفيل القطع المطور مناسب لتقطيع سعف النخيل، مما يزيد من كفاءة آلات الدراس الثابتة والمنتشرة انتشارا واسعاً في جميع أنحاء جمهورية مصر العربية.