DEVELOPMENT OF A FODDER BALES CHOPPER

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ABSTRACT

The aim of the present study is to develop, construction and to evaluate the performance a fodder-bales chopper. The developed fodder-bales chopper consists of frame, chopper drum (cutting knives - hammers mills - cutting knives and hammers mills), feeding platform and feeding housing. Theoretical analysis was conducted to estimate the chopper shaft diameters so as to save it from over loads and high stresses. The studied performance factors are chopping-knives drum speeds 560, 750, 850 and 1040 rpm, number of knives is 84 for cutting knives and 77 for hammers and bale types (wheat and rice). The performance of the developed fodder bales chopper was evaluated in terms of average and percentage of cutting length, chopping efficiency, required power, energy requirements and operational cost. The main results can be summarized in the following points. The maximum machine productivity values were (785.5 and 830.7 kg/h), the maximum required power values were (20.86 and 22.64 kW), the maximum chopping efficiency values were (96.8 and 97.4%), the minimum average length of cut values were (2.6 and 1.54 cm). Mminimum operating cost values were 19.1 and 21.5 L.E/ton at wheat straw bale and rice straw bale, respectively by using combined knives with hammers at drum speed of 1040rpm.

1. INTRODUCTION

Farms in the production of animal breeding, feed is stored in the form of bales (alfalfa, rice straw, wheat) for transportation and handling, but when presented as animal food be a problem and the difficulty of feeding of the animal. So this search for resolving this problem by developing for cutting and chopping bales necessary. **Khader (1997)** developed a simple chopping system using field crop residues in small farm. He studied the effect of the following factors: (a) chopping-drum speed, (b) number of cutting-drum knife and (c) clearance between

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fixed and rotating knives on the cutting length and efficiency. The residues used were rice straw, cotton and maize bean. He concluded that the four movable knives could be used for producing animal fodder, silage or compost according to residues cutting length. Where, the cutting length was affected by drum speed and clearance. And he studied the interaction effect between different speeds of cutter head and number of knives for cutting some field crop residues. Also, found that by increasing number of knives and cutter head drum speed the cutting length decreased. The optimum operating condition were: (a) Animal fodder 1.5 - 3 cm, drum speed of 1850 rpm and 1mm clearance and (b) Silage 3 – 6 cm and composting 6 - 12 cm, drum speed 1250 rpm and 5 mm clearance. The cutting efficiency value was 50 % for rice straw, at recommended cutting length. **Von Bargen et al. (1981)** reported that the corn residues used more energy among three crop residues tested viz. wheat straw, corn residues and grain sorghum residues at a hammer mill peripheral speed of 15.8 m/s. They also found that the grain sorghum residues required the least specific energy. **Yonis et al. (2001)** developed a crop residues chopper to improve its performance and productivity to be suitable for chopping rice straw. The development of the original machine is supplying a pre-cutting device to reduce the required chopping time and increase the machine productivity. They studied the rotor speed, cutting-length percentage and productivity to evaluate its performance. The results indicated that, productivity was 0.95 ton/h and cutting-length percentage of 1 - 9 cm reached 95 % for the total amount of cutting residues at 2000 rpm rotor speed. **Mani et al. (2004)** studied grinding performance and physical properties of wheat and barley straws, corn stover and switchgrass. They showed that among the four materials, switchgrass had the highest specific energy consumption (27.6 kW h t^{-1}), and corn stover had the least specific energy consumption (11.0 kW h t^{-1}) at 3.2 mm screen size. Total specific energy for particle size reduction of wheat straw using a 1.6-mm hammer mill screen size was twice that for a 3.2-mm screen size. In the case of switchgrass, a specific energy of 44.9 kW h t^{-1} was required for a screen size of 5.6 mm using a hammer mill. **El-Hanfy and Shalby (2009)** showed that the power consumption for cutting rice straw increased by increasing of both forward speed and cutting speed. The minimum value of power consumption of 15 kW was obtained at 0.35 m/s forward speed and 450 rpm cutting speed. While, the specific energy increased by decreasing forward speed and increasing cutting speed. The minimum value of specific energy of 25 kW h t^{-1} was obtained at forward speed of 0.75 m/s and cutting speed 450 rpm. **Tavakoli et al. (2009)** studied the effects of drum speed, screen size and number of blades on each flange on the power requirement for the size reduction of wheat straw. They reported that the power requirement increased with increasing of drum speed (from 500 to 800 rpm) and decreasing of screen size (from 4 cm to 2.5 cm) and number of blades (from 8 to 4) in each flange. The power requirement for the size reduction of wheat straw ranged between 0.985-5.377 kW and the average power requirement was 2.763 kW. **Basuiony et al (2015)** indicated that by increasing cutting rotor speed and decreasing moisture-content the productivity increased by using swinging and rotating knives. It was concluded that the higher productivity rice-straw cutting of 1.15 ton/h was obtained at 31.4 m/s rotor speed, 10.45 % moisture content and using swinging knife type.

The objectives of this study:

1- Develop; construct and performance test a developed fodder-bale chopper;

2- Study the effect of performance factors such as: cutting drum speed, cutting-blade and fodder-bale types on average cutting length, machine productivity, power and specific energy and

3- Study the cost analysis of using the developed fodder-bale chopper.

2- MATERIALS AND METHODS

The experiment was conducted at Kafer El- Hamam Research station in the season of 2015.

2-1 Materials

2-1-1 Developed fodder bales chopper:

The developed fodder bales chopper consists of the following parts (Fig. 1):

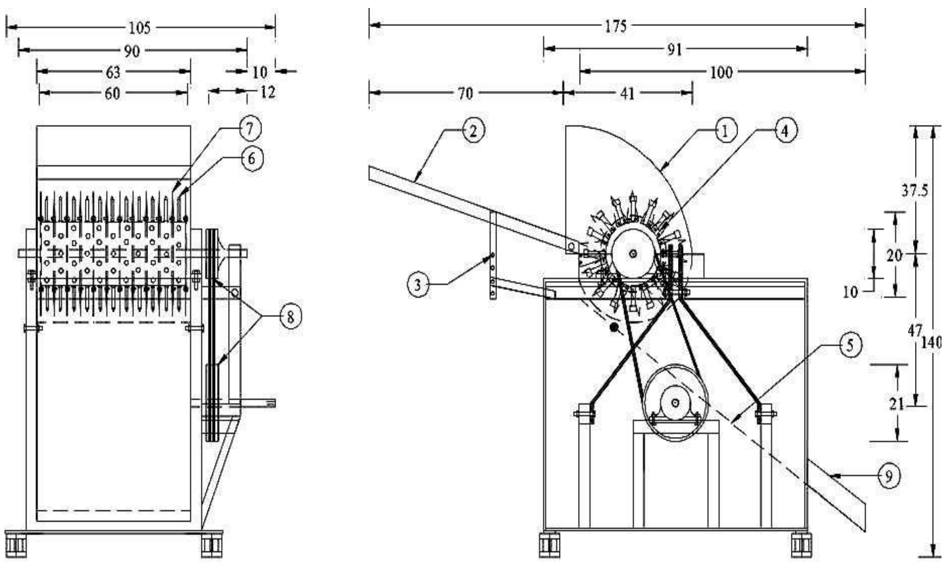
(a) Frame: the frame was made of iron sheet with thickness of 5mm. The main dimensions of the frame are 900 mm length, 750 mm width and 920 mm height.

(b) Feeding platform: the feeding platform was made of iron sheet with thickness of 2 mm, length of 1200 mm, width of 630 mm, height of 20 mm and inclined angle of 35º.

(c) Chopping drum: the chopping drum was made of steel pipe with thickness of 5 mm, diameter of 150 mm, and length, of 600 mm.

(d) Chopping knives:

(e) (d-1) Cutting knives: The Cutting- knives Fig. 2 was made of steel sheet with thickness of 3 mm, batten width of 60 mm, and height of 70 mm, top width 4 mm, the number of knives were 84 (number of knives rows 7, number of knives\row 12, spacing between two consecutive knives, 50 mm and Spacing between consecutive two knives/row, 25 mm).



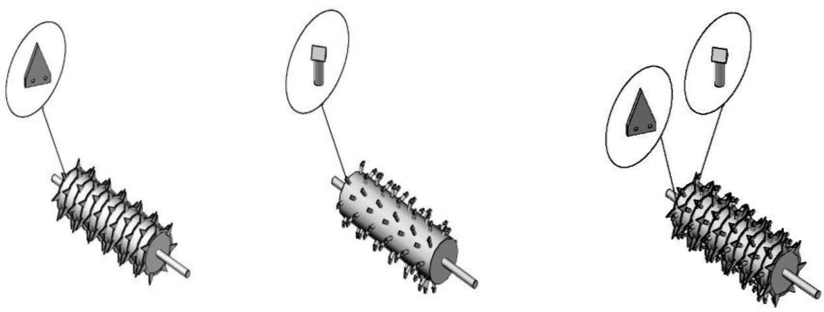
S. view Elevation

1	Feeding housing	5	outlet duct
2	Feeding platform	6	The hammers
3	Plat form angle regulator	7	The knives
4	Chopping drum	8	Pulleys

Fig. 1: Side view and elevation of the developed fodder bales chopper.

(a) **(d-2) Hammer mills:** The hammer mills were made of steel bolts with diameter 10 mm, and length of 120 mm. The forged length, top width and bottom width were 30 mm, 15 mm, and 5 mm, the number of hammer were 77 (number of hammers rows 7, number of hammers\row 11, Spacing between two hammers, 50 mm, Spacing between two hammers row, 70 mm. Fig. 2. Three types of hummer mill blades are used, first triangular blades shape, second peg hummer mill blades shape and third the combined of previous two types.

(b) **Feeding housing:** The feeding housing was made of iron sheet with 2 mm thickness, length of 630 mm, width of 450 mm, and height of 450 mm.



(a) Cutting (b) Hammer (c) Combined

Fig. 2: Isometric types of the three tested chopping-knives.

(h) Concave screen: The Concave screen was made of galvanized iron sheet with 3 mm thickness, diameter 345 mm, length 650 mm, hole diameter 120 mm and Pegs concave bar clearance 50 mm.

(i) The transmission system: The machine is operated by means of machine pulleys and belts powered from tractor PTO.

2.2. The tractor:

A four wheel tractor of the standard type was used as a power source with the following specifications: model Naser 65, Engine type diesel, 4 cylinders, Power at rated speed 65 hp (48 kW), P.T.O revolution, 540-1000 rpm and Mass 2250 kg.

2.3: Tested fodder bales:

Table (1) shows some physical properties of tested fodder bales are used.

2-4: Methods:

The developed rice-straw and wheat bales chopper was tested in Kafer El-Hamam, Agricultural Research Station, Sharkia Governorate, (ARC), Egypt to develop the fodder bales chopper during summer season of 2015.

Table (1): Some physical properties of tested fodder bales are used.

Properties	Bale variety	
	Wheat straw bale	Rice straw bale
Length of bale, cm	110	110
Width of bale, cm	40	40
Height of bale, cm	45	45
Average of stem length, cm	75-85	55-70
Mass of bale, kg	12	15

2.4. 1: Studied parameters: Experiments were conducted to study some factors affecting the performance of the developed chopper. Primary tests were carried out to choose the studied-parameter ranges. The studied parameters were as follows:

- Four different chopper drum speeds of 560, 750, 850 and 1040 rpm (6.68, 8.95, 10, 14 and 12.41 m/s)

- Two different types of bales (wheat bales and bales)

- Three different types of chopper drum blades (Fig. 2):

(a) Cutting-knives drum, using 84 knives were tested.

(b) Hammer mill drum, Using 77 hammers were tested.

(c) Combined Cutting-knives and hammer mill.

2-4.2: Measurements:

(1) Average and percentage cutting-length of rice and wheat straw.

Average of cutting length was measured from chopped rice and wheat-straw sample of 200 g for each treatment. The four categories of < 4 cm, 4 - 8 cm, 8 – 12 and > 12 cm were measured. Also each cutting length in the sample was weighed and calculated as a percentage from the total weight of the sample (**Iraqi and Khawaga, 2003**).

(2) Machine productivity.

Machine productivity was calculated by using the following equation (**Mady, 1999**).

$$P = W / t \qquad \text{--------------------------------- (3-1)}$$

Where, P: Machine productivity, kg/h, W: Mass of the rice or wheat straw bale, kg and t: Time, h.

(3) Required power:

The required power (P) during the chopping operation was estimated from the rate of fuel consumption of the tractor to refill the fuel tank. Chopping power was estimated by using the following equation. (**Barger et al., 1963**)

$$P = Fc \times \frac{1}{60 \times 60} \times LCV \times \rho_f \times 427 \times \eta_{th} \times \eta_m \times 1/75 \times 1/1.36, kW \text{ W}$$

here:

Fc: The fuel consumption, L/h., ρ_f : The density of fuel, 0.85 kg/L.

LCV: Lower calorific value of fuel, (11000 k Cal/kg)

427 : Thermo- mechanical equivalent, kg. m/ k Cal.

ηth : thermal efficiency of the engine, (30 -35%).

ηm : the mechanical efficiency of the engine,(80-85%).

$$P = Fc \times 2.98 \text{ kW}$$

(4) Specific Energy requirements:

Specific energy requirements were estimated by using the following equation:

$$\text{Energy requirements (kW.h/ton)} = \frac{\text{required power, kW}}{\text{Machine productivty, ton/h}}$$

(5) Cost analysis:

The operational cost was determined from the following formula:

Operational cost, LE/ton = Hourly cost, LE/h / machine productivity, ton/h.

3- RESULTS AND DISCUSSION

1- Effect of same operating parameters on average cutting-length.

Fig.3 shows the effect of cutting-drum speed, drum blades and fodder-bale types on average cutting-length. The results show that by increasing drum speed, the average cutting-length of wheat and rice straw decreased. By increasing drum speed from 560 to 1040 rpm, the average cutting-length of wheat straw decreased from 6.1 to 3.9, from 7.7 to 4.84 and from 4.3 to 2.6 cm at using knives, hammers and knives with hammers respectively. By increasing drum speed from 560 to 1040 rpm the average cutting-length of rice straw decreased from 5.85 to 3.7, from 7.1 to 4.84 and from 3.5 to 1.54 under the same previous conditions. The maximum average cutting-length values of wheat and rice straw of (7.7 and7.1 cm) were obtained by using cutting-hammers at speed of 560 rpm. Meanwhile, the minimum average cutting-length values of wheat and rice straw of (2.6 and 1.54 cm), respectively was obtained by using cutting-knives with hammers at speed of 1040.The decreasing of average cutting-length of wheat and rice straw by increasing drum speed is due to increasing number of impacts of knives with hammers on straw.

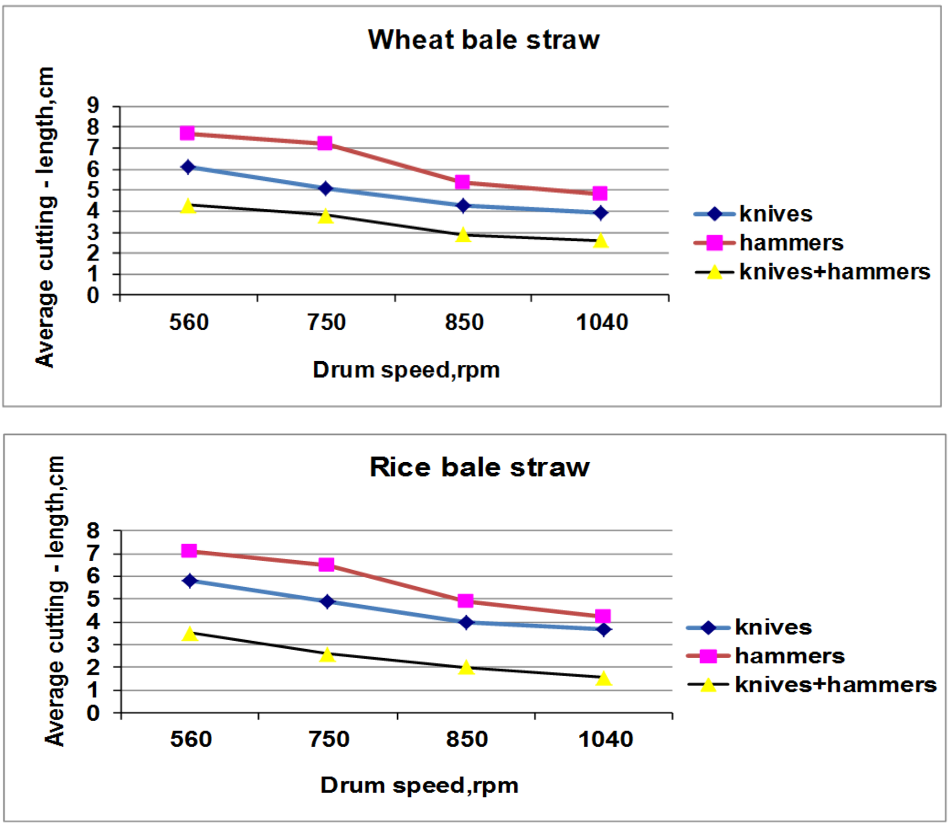


Fig. 3: Effect of cutting-drum speed, drum blades and fodder-bale types on average cutting-length.

2- Effect of same operating parameters on cutting-length percentage.
Fig. 4 indicates the effect of cutting-drum speed, drum blades and fodder-bale types on cutting-length percentage. The results show that by increasing drum speed cutting-length percentage of wheat and rice straw decreased. By increasing drum speed from 560 to 1040 rpm the cutting-length percentage of wheat straw decreased from 7.6 to 4.8, from 9.6 to 6.0 and from 5.3 to 3.2% at using knives, hammers and knives with hammers, respectively. By increasing drum speed from 560 to 1040 rpm, cutting-length percentage of rice straw decreased from 9.7 to 6.2, from 11.8 to 7.0 and from 5.8 to 2.6% under same conditions.

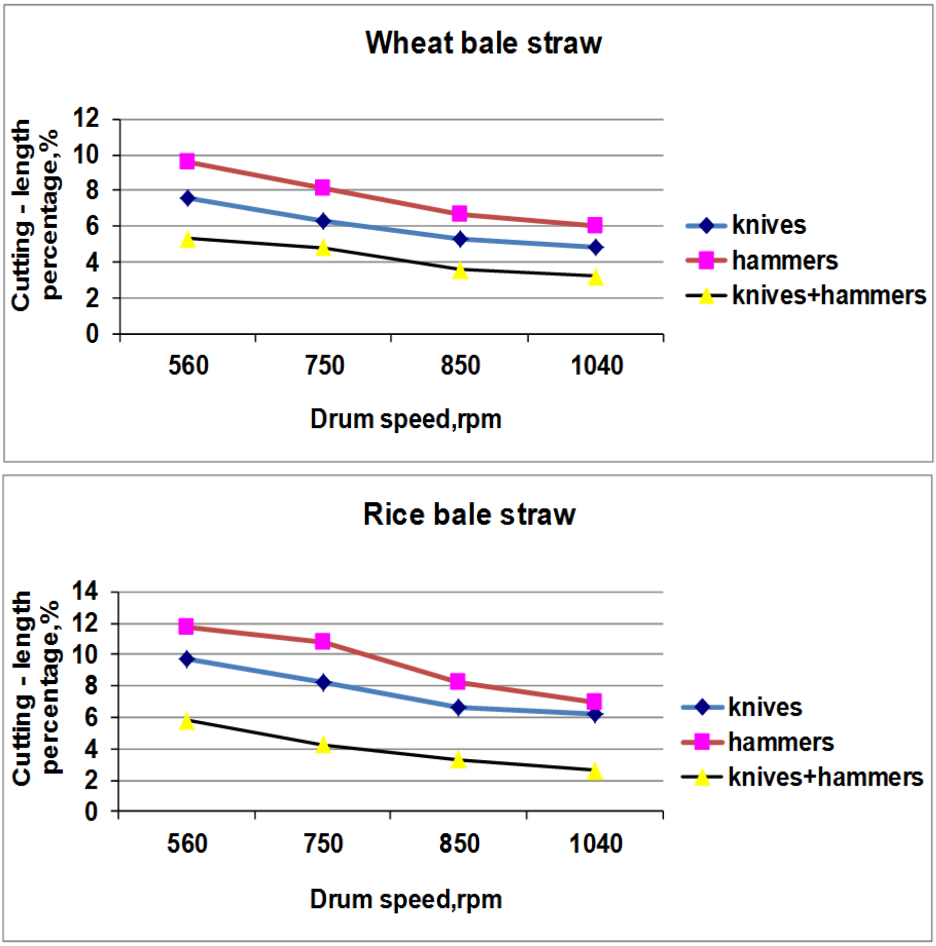


Fig. 4: Effect of cutting-drum speed, drum blades and fodder-bale types on cutting-length percentage.

The maximum cutting-length percentage of wheat and rice straw of (9.6 and 11.8 %) were obtained by using cutting-hammers at speed of 560 rpm. Meanwhile, the minimum cutting-length percentage of wheat and rice straw of (3.2 and 2.6 %), respectively were obtained by using cutting-knives with hammers at speed of 1040. The decreasing of cutting-length percentage of wheat and rice straw by increasing drum speed is due to increasing number of impacts of knives with hammers on straw.

3- Effect of same operating parameters on chopping efficiency.

Fig. 5 shows the effect of cutting-drum speed, drum blades and fodder-bale types on chopping efficiency.

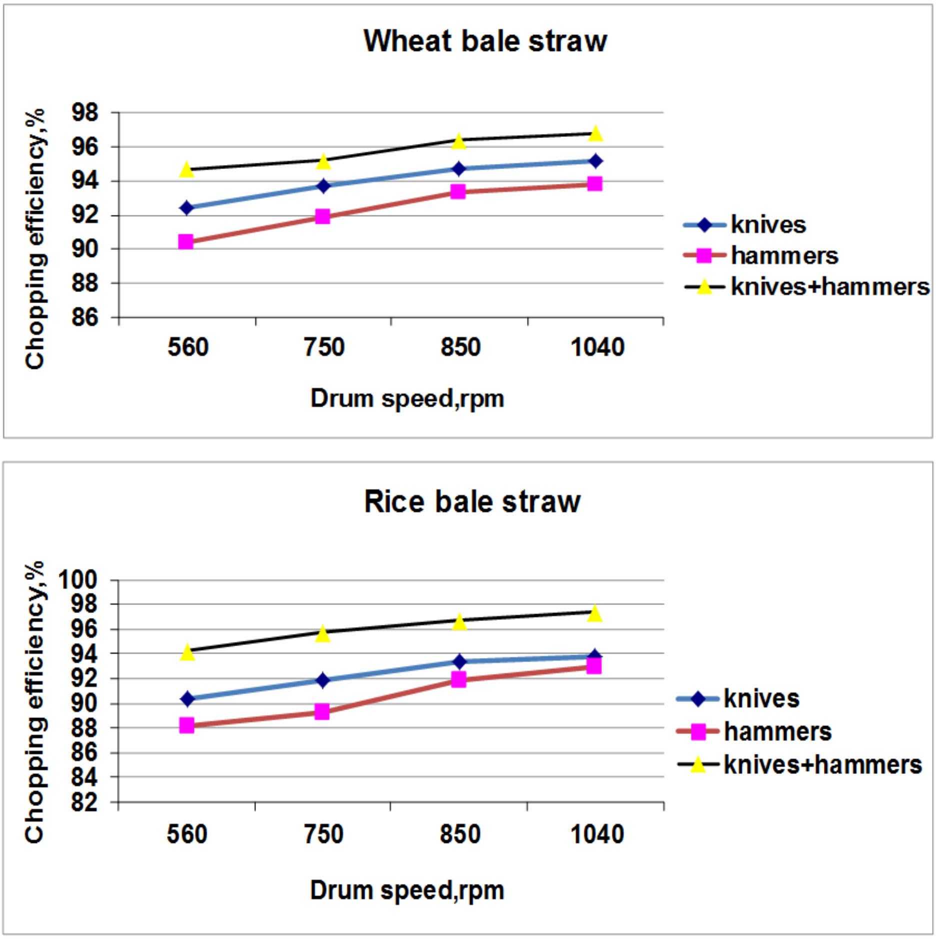
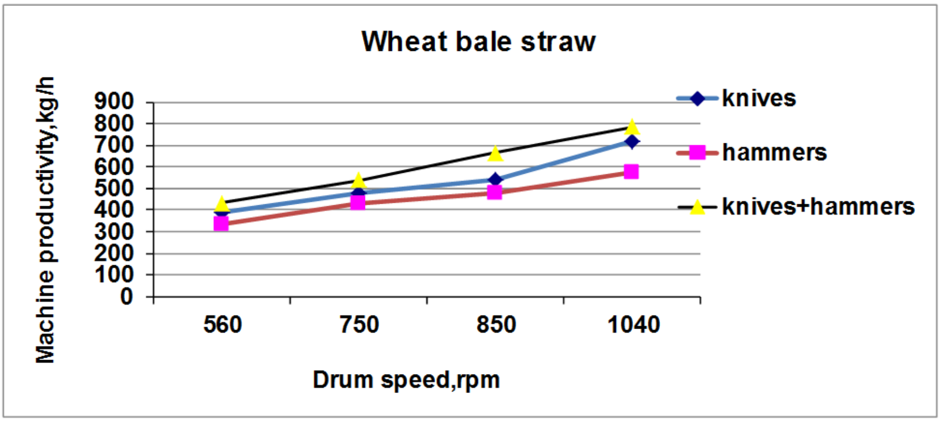


Fig. 5: Effect of cutting-drum speed, drum blades and fodder-bale types on chopping efficiency.

The results show that by increasing drum speed chopping efficiency of wheat and rice straw increased. By increasing drum speed from 560 to 1040 rpm, chopping efficiency values of wheat straw increased from 92.4 to 95.2, from 90.4 to 93.8 and from 94.7 to 96.8% at using knives, hammers and knives with hammers, respectively. By increasing drum speed from 560 to 1040 rpm, chopping efficiency of rice straw increased from 90.3 to 93.8, from 88.2 to 93 and from 94.2 to 97.4% under the same previous conditions. The maximum chopping efficiency values of wheat and rice straw of (96.8 and 97.4 %) were obtained by using cutting-knives with hammers at speed of 1040. Meanwhile, the minimum chopping efficiency values of wheat and rice straw of (90.4 and 88.2 %), respectively were obtained by using cutting-hammers at speed of 560 rpm. The increasing of chopping efficiency by increasing drum speed is due to increasing number of impacts of knives with hammers on straw and decreased the cutting - length.

4- Effect of same operating parameters on machine productivity.

Fig. 6 shows the effect of cutting-drum speed, drum blades and fodder-bale types on machine productivity. The results show that by increasing drum speed, machine productivity of wheat and rice straw increased. By increasing drum speed from 560 to 1040 rpm, machine productivity of wheat straw increased from 392.7 to 720, from 332.3 to 576 and from 432 to 785.5 kg/h at using knives, hammers and knives with hammers, respectively. By increasing drum speed from 560 to 1040 rpm, machine productivity of rice straw increased from 415.4 to 675, from 360 to 568.4 and from 490.9 to 830.7 kg/h under the same conditions. The maximum machine productivity values of wheat and rice straw of (785.5 and 830.7 kg/h) were obtained by using cutting-knives with hammers at speed of 1040 rpm. Meanwhile, the minimum machine productivity values of wheat and rice straw of (332.3 and 360 kg/h), respectively were obtained by using cutting-hammers at speed of 560 rpm. The increasing of machine productivity by increasing drum speed is due to increasing number of impacts of knives with hammers on straw, feeding rate and little of time work.



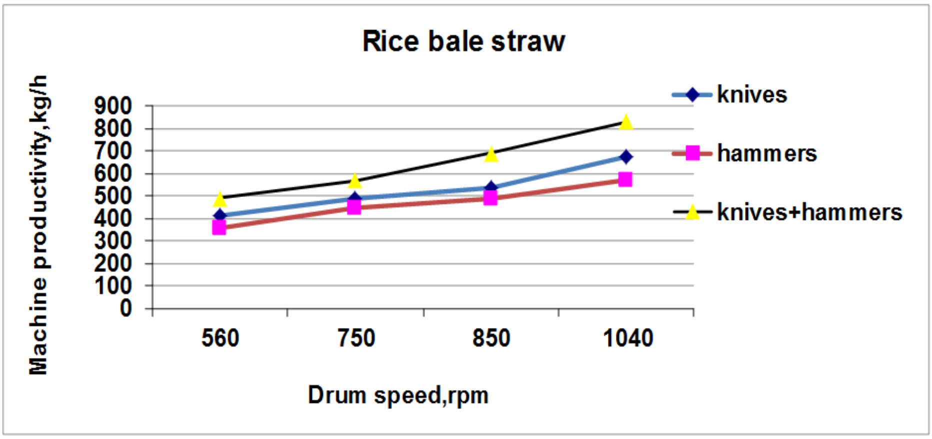
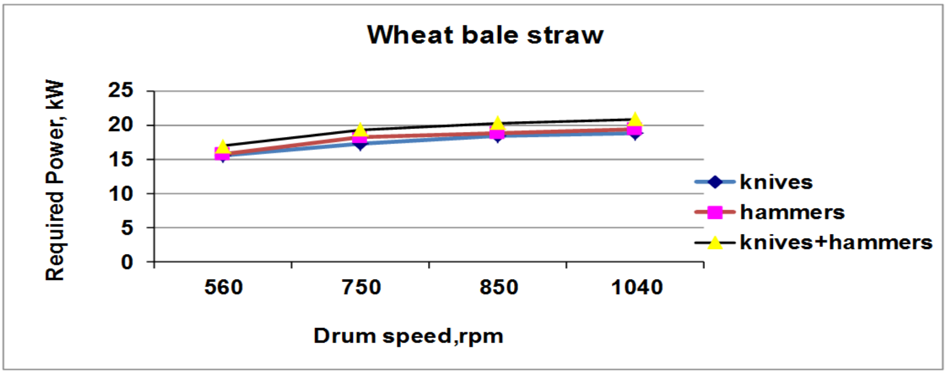


Fig**. 6: Effect of cutting-drum speed, drum blades and fodder-bale types on machine productivity.**

5- Effect of same operating parameters on required power.

Fig. 7 shows the effect of cutting-drum speed, drum blades and fodder-bale types on power requirement. The results show that by increasing drum speed required power of wheat and rice straw increased. By increasing drum speed from 560 to 1040 rpm, power requirement of wheat straw increased from 15.49 to 18.77, from 15.79 to 19.37 and from 16.98 to 20.86 kW at using knives, hammers and knives with hammers, respectively. By increasing drum speed from 560 to 1040 rpm, power requirement of rice straw increased from 16.68 to 20.86, from 16.98 to 21.45 and from 18.17 to 22.05 kW under the same previous conditions. The maximum power requirement values of wheat and rice straw of

(20.86 and 22.05 kW) were obtained by using cutting-knives with hammers at speed of 1040rpm. Meanwhile, the minimum power requirement values of wheat and rice straw of (15.49 and 16.68 kW), respectively were obtained by using cutting-hammers at speed of 560 rpm. The increasing of power requirement by increasing drum speed is due to increase of fuel consumption.



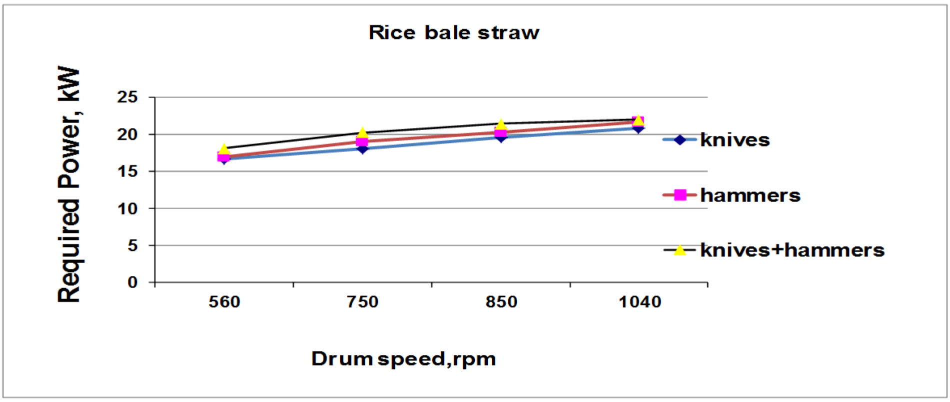
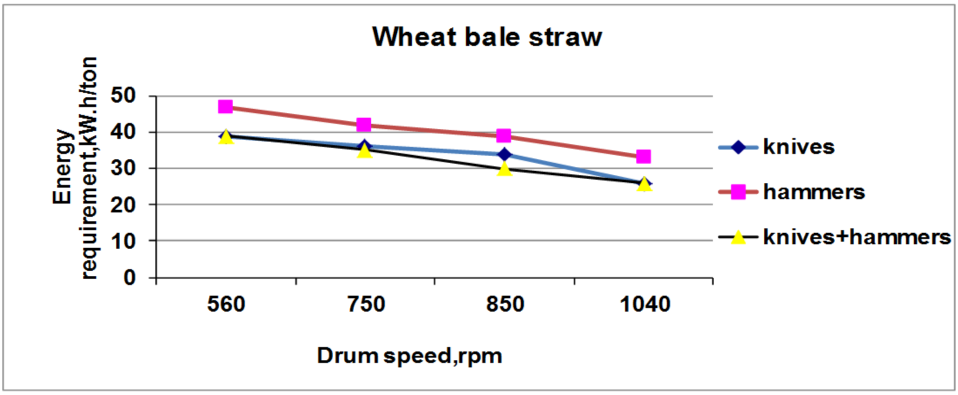


Fig. 7: Effect of cutting-drum speed, drum blades and fodder-bale types on power requirement.

6- Effect of same operating parameters on energy requirement.

Fig. 8 shows the effect of cutting-drum speed, drum blades and fodder-bale types on energy requirement .The results show that by increasing drum speed, energy requirement of wheat and rice straw decreased. By increasing drum speed from 560 to 1040 rpm, energy requirement of wheat straw decreased from 39 to 26, from 47 to 33 and from 39 to 26kW.h/ton at using knives, hammers and knives with hammers, respectively. By increasing drum speed from 560 to 1040 rpm, energy requirement of rice straw decreased from 40 to 30, from 47 to 37 and from 37 to 26 kW. h/ton under the same conditions. The maximum energy requirement of wheat and rice straw of (47 and 47 kW.h/ton) were obtained by using cutting-knives with hammers at speed of 1040rpm. Meanwhile, the minimum energy requirement values of wheat and rice straw of (26 and 26 kW. h/ton), respectively were obtained by using cutting-hammers at speed of 560 rpm. The increasing of energy requirement by increasing drum speed is attributed to that increasing of the fuel consumption and power required rate is lower than increasing in the machine productivity rate.



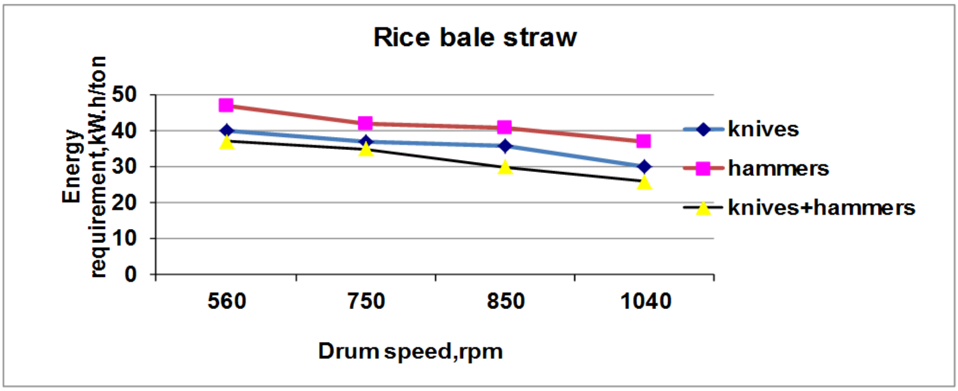


Fig. 8: Effect of cutting-drum speed, drum blades and fodder-bale types on energy requirement.

7- Effect of same operating parameters on operational cost.

Fig. 9 and 10 shows the effect of cutting-drum speed, drum blades and fodder-bale types on hourly cost. The results show that by increasing drum speed from 560 to 1040 rpm hourly cost of wheat straw increased from 11.62 to 13.41, from 11,78 to 13.73 and from 12.43 to 14.54 LE/h at using knives, hammers and knives with hammers, respectively. By increasing drum speed from 560 to 1040 rpm, operation cost of rice straw increased from 12.24 to 14.54, from 12.43 to 14.86 and from 13.08 to 15.18 LE/h under the same previous conditions.

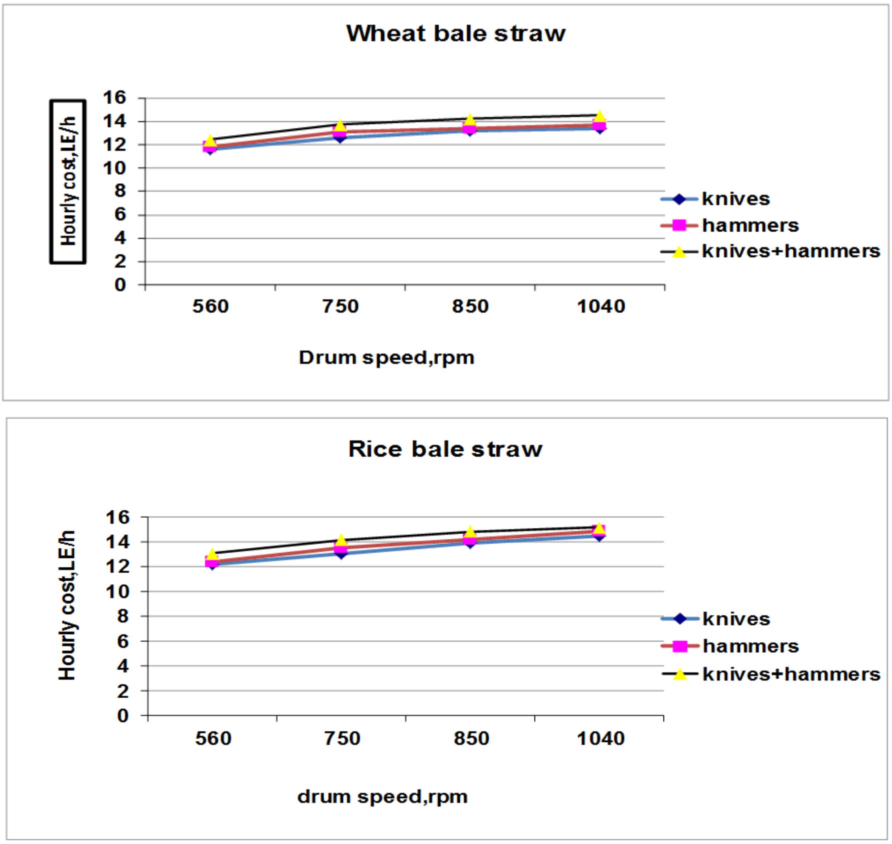


Fig. 9: Effect of cutting-drum speed, blade and fodder-bale types on operation cost.

But by increasing drum speed from 560 to 1040 rpm operated cost of wheat straw decreased from 29.6 to 18.6, from 35.4 to 23.8 and from 28.7 to 19.1 LE/ton at using knives, hammers and knives with hammers, respectively. By increasing drum speed from 560 to 1040 rpm, operation cost of rice straw decreased from 29.4 to 21.5, from 34.5 to 26.1 and from 26.6 to 21.5 LE/ton under the same previous conditions.

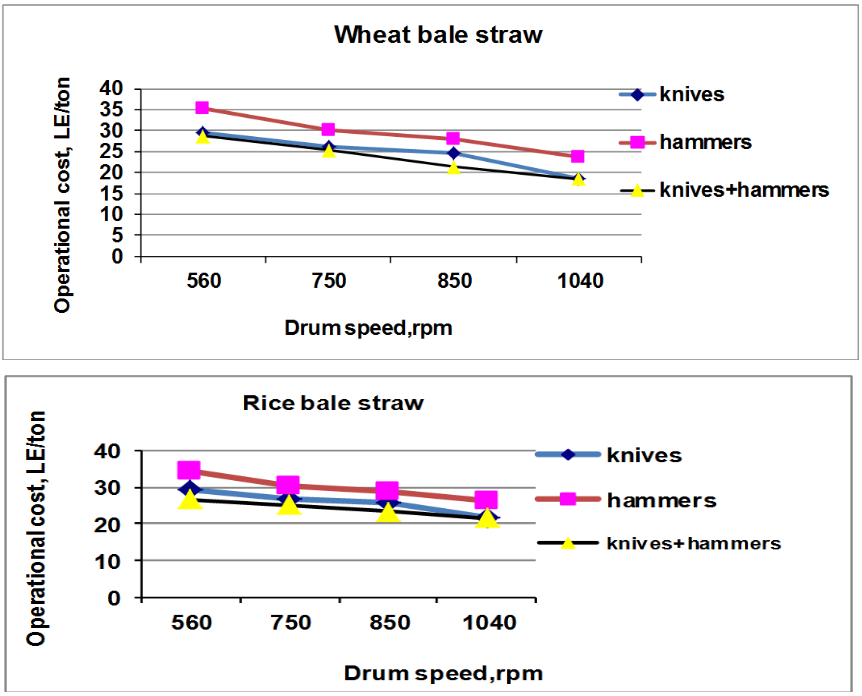


Fig. 10: Effect of cutting-drum speed, blade and fodder-bale types on product cost.

4- CONCLUSION

The recommendations of this study can be summarized as follows points

1- It can transform bales of fodder to easy image to feed the animal and reduce losses of bales strewn by using the developed bales chopper.

2- The maximum values of both chopping efficiency and machine productivity of (96.8 and 97.4%) and (785.5 and 830.7 kg/h) at wheat straw bale and rice straw bale respectively, while the minimum operating cost of 19.1 and 21.5 L.E/ton at wheat straw bale and rice straw bale, were achieved by using combined knives and hummers at drum speed of 1040 rpm.

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الملخص العربى

تطوير آلة لفرم بالات الاعلاف

عادل احمد ابراهيم الجيزاوى[١] ، سها جمال عبد الحميد[١] و عاطف غندور[٢]

فى مزارع تربية الإنتاج الحيوانى يتم تخزين العلف فى صورة بالات (البرسيم، دريس قش الارز،القمح) لسهولة النقل والتخزين ولكن عند تقديمه كغذاء للحيوان يكون هناك مشكلة وصعوبة لتغذيته للحيوان.

لذلك يتطرق البحث لهذه المشكلة وحلها عن طريق تطوير آلة لتقطيع وفرم البالات لتقديمه للحيوان بصورة سهلة.

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- أهداف هذه الدراسة:

١- تحويل بالات الأعلاف الى صورة سهلة لتغذية الحيوان باستخدام آلة فرم البالات المطورة.

٢- دراسة تأثير عوامل الأداء مثل: سرعة درفيل القطع- ونوع شفرات القطع على إنتاجية الآلة والقدرة والطاقة ومتوسط طول القطع.

٣- تقييم الآلة المطورة إقتصادياً.

وتتكون هذه الآلة من مدخل البالة، درفيل فرم البالة، صدر الدرفيل، مخرج القش المفروم.وفكرة عمل الالة وجود مدخل البالة وعبارة عن حامل مثبت بميل على غرفة الفرم ومن خلاله يتم تغذية البالة الى غرفة الفرم وهى عبارة عن درفيل بداخله عمود تم قياس الاجهادات عليه وقد تم استخدام نوعين من أسلحه الفرم وكانت من المتغيرات التى تم اتخاذها للبحث:

١- درفيل سكاكين مشرشرة حادة القطع مثبتة على ١٢ صف وفى ك ل صف ٧ سكاكين بشكل متبادل مع الصف التالى.

٢- درفيل مطارق حادة من أعلى القمة مثبتة على ١١ صف وفى كل صف ٧ مطارق بشكل متبادل مع الصف التالى.

٣- درفيل السكاكين و المطارق معا بشكل متبادل صف سكاكين يليه صف مطارق.

للجرار ويوجد لوح من الصاج بسمك ٢مم للحصول على القش المفروم ويكون أسفل صدر درفيل الفرم PTO مصدر حركتها

وتم اخذ نوعين من البالات قش الأرز وبالات القمح مع اخذ اربع متغيرات لسرعة درفيل القطع (٥٦٠، ٧٥٠، ٨٥٠، ١٠٤٠لفة / دقيقة

وتم الحصول على النتائج التالية:

١- متوسط طول القطع اقل متوسط طول قطع كان (٢.٦ ، ١.٥٤سم)لقش القمح ولقش الارز عند استخدام اعلى سرعة ١٠٤٠ لفة /دقيقة مع درفيل السكاكين والمطارق معا.

٢- كفاءة الفرم أعلى كفاءة فرم تم الحصول عليها (٩٦.٨ ،٩٧.٤%) لقش القمح ولقش الارز عند استخدام اعلى سرعة ١٠٤٠ لفة /دقيقة مع درفيل السكاكين والمطارق معا.

٣- الإنتاجية كانت أعلى إنتاجية تم الحصول عليها (٧٨٥.٥، ٨٣٠.٧كجم/ساعة) لقش القمح ولقش الارز عند استخدام اعلى سرعة ١٠٤٠ لفة /دقيقة مع درفيل السكاكين والمطارق معا.

٤- متطلبات الطاقة. أعلى متطلبات للطاقة تم الحصول عليها (٤٧ و٤٧ ك.وات.س/طن) لقش القمح وقش الأرز عند استخدام درفيل السكاكين مع المطارق وعند سرعة درفيل ١٠٤٠ لفة/ الدقيقة . بينما تم الحصول على الحد الأدنى من متطلبات الطاقة (٢٦ و ٢٦ ك.وات.س/الطن) عند استخدام درفيل المطارق وعند سرعة ٥٦٠ لفة/الدقيقة.

٥- تكاليف المنتج أقل تكلفة تم الحصول عليها عند استخدام درفيل السكاكين مع المطارق وعند سرعة ١٠٤٠ لفة /دقيقة حيث كانت تكاليف المنتج (١٩.١، ٢١.٥جنية /طن) لقش القمح ولقش الارز.