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Requirements Of Balling Chopped Rice Straw

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ABSTRACT

This study aimed to identify the effect of the rice straw chopping process on the bales storage capacity. Chopping process of straw rice was carried out under three drum speeds, three feeding rates and three moisture contents of straw. Baling process was used to press chopped straw with three frequency speeds of plunger to press chopped straw, three feeding rates for chopped rice straw and different cutting lengths for chopped rice straw. The results were obtained the lowest average cutting length was7.88 mm with increasing speed of drum from 4.71 to 10.5m/s, and the minimum moisture content at 12%. The highest bale density was 144.6 kg / m³,under the frequency of press speed 0.45 m /s, for cutting length averages of less than 10 mm. The lowest storage capacity was 16.46 m³/fed, with a maximum compressing speed of 0.45 m /s and a feeding rate of 1.5Mg /h with the use of cutting averages less than 10mm. For the chopping process, the lowest energy requirement was8.9 kW.h/Mg at 4.71m/s and 12% moisture content with feed rate of 1.5Mg /h. Otherwise for the baling process, the lowest energy requirement was 5.67 kW.h /Mg at a compression speed of 0.24 m /s, feed rate of 3Mg/h and average cutting lengths greater than 20.5mm. The lowest production cost obtained when chopping straw was79.7LE /Mg with a speed of 4.71m/s, a moisture content of 12% and a feed rate of 1.5 Mg/h. The lowest production cost obtained when baling chopped straw was 98.5LE/ Mg with a speed of 0.24m /s and feeding rate of 3Mg /h.

Keywords: rice straw - chopping - baling- storage

INTRODUCTION

The cultivated area of rice is about 1.3 million feddans in year 2019 that produced about 2.1 million Mg rice straw.(the production per feddan is about 1.6 Mg/fed) recorded by Technical Recommendations Bulletin for the Rice Crop (2020). El-Berry *et al*., (2001) reported that 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 Cutting rice straw into small pieces is a simple and effective way to be suitable for storage, handling and recycling to suit the many uses. Al-Gezawe *et al*. (2016)indicted that the performance of the developed fodder bales chopper. They found that the maximum machine productivity value was830.7 kg/h, the maximum required power values was 22.64 kW, the maximum chopping efficiency value was 97.4%, the minimum average length of cut value was 1.54 cm. Minimum operating cost value was 21.5 LE/ton at rice straw bale by using combined knives with hammers at drum speed of 1040 rpm. Basiouny*et al*.(2015) showed that the highest percentage of cutting rice straw lengths of <30mm (56.89%) which is suitable for animal feed and the highest percentage of cutting rice straw lengths of 30-60mm (29.31%) also the minimum percentage of >60mm category(13.8%) obtained under rotor speed of 31.4m/s and moisture contentof 10.45% . Also, results noticed that the higher productivity when cutting of rice straw is1.15Mg/h. Khairy (2015) found that the maximum productivity was 6.03 kg/h and the optimum specific energy requirement of 52.08 kW.h/Mg were obtained at drum speed of 1600 rpm, 6 knives, gate angle of 180˚ and concave holes diameter of 10 mm. Ismail *et al*., (2012) found that the highest value straw cutting factor percentage was99.60 % 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. Mohamed *et al*.,(2001) developed and evaluated a rice straw chopper. Their results indicated that the productivity of the developed machines was 0.95 Mg/h at 2000 rpm rotor speed and the cutting lengths of (10 - 90 mm) reached 95.25% from the total amount of cutting residue. Embabi, (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 with feeding rate of 1.873 Mg/h. Bahnas and Al-Jayyar (2002) mentioned that the agricultural residual must be recycled to preserve the environment from pollution and to collect the small area holdings that have the rice straw in a large piece that increases the bailing performance and the results indicated that there was an increase in the mechanical baler field capacity and field efficiency, consequently, energy requirements and baling costs decreased with increasing the holding areas. When the forward speed increased from 2 to 5 km/h, there was an increase in the field capacity by 69.7 % and a decrease in field efficiency by 19.03 %. Afify *et al*., (2002) stated that

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the baler productivity and the bale density increased by about 25% and 30% as the baler feeding rates increased from 1.5 to1.8 Mg/h. and from 1.8 to 2.2 Mg/h, respectively. The total cost of baling decreased with an increase of the baler feeding rates. The highest value of the total cost of baling 284.4 L.E./fed was obtained at the lowest level of the baler feeding rate 1.5 Mg/h. The total cost of baling decreased by about 30% when the baler-feeding rate increased from 1.8 to 2.2 Mg/h. Hegazy(2015)mentioned that testing and evaluation of the baler gave chance to enhance baling mechanism and its reliability. The relations between straw characteristics, moisture content (MC) and bales density have been addressed, where 244.63 kg/m³ average bales density obtained from threshed straw with 19.84 % average MC with 23.63 kg average weight. For lower MC, 6.31, 7.77 and 8.21 % bales density were 130.37, 145.63 and 137.53 kg/ m³, respectively for different rice straw. Baling straw with same characteristics at different MC reduced bales density by 21.3 % when MC reduced from 25.23 to 7.77 %. Baling shorter straw gave higher bales density with 293.22 kg/m³ with 28.33 kg average bales weight. Rice straw baled under low moisture content when gets stored indoors for 22 days, always had an increase in its moisture content as well as the density. Also, for the verities that stored indoors long time (62 days), moisture content increased. El- Saied *et al*., (2009) reported that feed rate increased linearly with increase in the drum speed, but the straw sizes decreased with increase in the drum speed and decreases in the moisture content of the material.

Due to the existence of collecting places for round rice straw bales, which occupy a large area due to their large size and weight and the difficulty of transporting these bales by workers, a rice straw chopping machine is used and then the chopped straw is compressed by Stationary baler that brings out the bales in the form of a parallelepiped rectangle. To feed animals or to make paper , reduce storage capacity and specific energy.

So, the present study aimed to study the effect of rice straw chopping on the bale density and storage capacity.

MATERIALS AND METHODS

The experiment was conducted at Senbelawin Center El –Daqhlia Government during summer season 2019

Chopper

The used local made chopper consists of the following components:

1.**Frame:** It was fabricated from U shape hollow galvanized steel of 1500, 450 and 1200 mm length, width and height, respectively.

2.**Feeding platform:** It was made of iron sheet of450, 360,4 and 20mm length, width, thickness and height, respectively. The feeding platform inclined angle is 15˚.

3.**Feeding device**: It consists of two counter-rotating rolls of 360 mm length diameter of 100mm, one of the rolls is curly and the other is smooth. which rotate in the opposite direction to pull the straw stems linked between them with a zipper that prevents the machine from turning when feeding.

4.**Chopping drum:** It consists of a steel cylinder of 200mm diameter and 360mm length. Four steel cutting knives were installed on the cylinder with an inclination of 25˚.The fork dimensions were 360,5 and 50 mm length, width and thickness, respectively.

5.**Transmission system:** The chopping drum was operated using means of pulleys and belts which were powered using 29.4 kW tractor at 540 rpm P.T.O.

The worker unpacks the rice straw bales with full stems and feeds them through the platform to feeding device and the chopping drum that contains the knives to chop the rice straw, and from it to the outlet tube.

- Stationary baler

The use locally made stationary baler f 2000 kg mass and 5800, 1800 and 1750 mm length, width and height, respectively. It is driven by means of belts and pulleys. The plunger stroke is 640 mm. The produced bale length, width and height are 1400x 550 x450 mm, respectively. The baler is operated using a tractor of 55.93 kW power. The plunger stroke was 640 mm run with 1200 cycles per hour, El-Shal (2005). Workers collect the chop straw and hand it to the baler feed worker. The straw stems are placed before adding the chopped straw to the baler feeding chamber so that the chopped straw does not fall and leak due to its small length. And with the movement of the El-Gorab, the chop straw is pressed from the top and the reciprocating movement of the piston is also compressing

-Round rice straw bales

Averages round rice straw bale with, 1100mm length, 1000mm diameter, and 280 kg mass. The average of rice straw stem length was 850mm.Round bales take up too much space and are difficult to transport and handle.

Studied parameters

-Studied parameters for chopping process

Three levels of chopper drum speeds of S1=4.71, S2=6.8 and S3= 10.5m/s.

Three moisture content of rice straw (w.d)Mc1=12, Mc2=15and Mc3=20%.

Three feeding rates of rice straw0.9, 1.2 and1.5Mg/h.

-Studied parameters for baller

Three levels of plunger speeds of Sp1=0.24, Sp2=0.34 and Sp3=0.45m/s

Three levels of feeding rate F1=1.5, F2= 2.1 and F3=3Mg/h.

Three levels of chopped rice straw length<10,10-20.5and >20.5mm.

The experiment was established as completely randomized design.

Measurements

1-The chopping process was evaluated according to the following parameters:

- Mean weight length was measured after chopper. Chopped straw samples of 200 g for each treatment had taken for lab calculations. The three categories of length<10, 10-20.5and >20.5mm were measured using screens with standard aperture diameters (10, 20 and 30 mm) are used, respectively, from top to bottom. A sample of known weight is taken from the chopped straw and placed on top of the sieve 30 mm. The sieves are shaken automatically until the straw settles on the different sieves, each cutting length in the sample was weighed and calculated as a percentage from the total weight of the sample (Iraqi and Khawaga, 2003).
- Moisture content: The moisture content of rice straw was determined according to ASAE S358 (ASAE 2003). Chopped rice straw pieces were oven-dried at 80°c until

reaching the fixed mass. The samples were weighted before and after drying and moisture content were determined.

2- The baler was evaluated according to the following parameters:

Bale density:

The obtained bales were weighted. The density was calculated by dividing bale mass per its volume.

Size requirements for storing bales:

Size requirements for storing bales were calculated using the following equation (1),El- Shal(2005):

$$S.R.S.B. = \frac{S.Y}{B.D} \quad \ldots\ldots(1)$$

S.R.S.B. = Size requirements for storing bales, m³/fed;
S.Y. = Straw yield, kg/fed;
B.D. = Bale density, kg/m³.

Coefficient of variation (C.V%):

Coefficient of variation was calculated according to Coates (1992) and Srivastava et al. (1995):

$$\delta = \sqrt{\frac{\sum (x - \bar{x})}{n-1}} \quad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where:

δ: Standard deviation

X: Mass of particle in each tray (g)
$\bar{x}$: Average mass of particles in all trays (g)
n: total number of collection trays

$$C.V = \frac{\delta}{\bar{x}} \times 100 \quad \ldots\ldots\ \ldots\ldots\ldots\ldots (3)$$

Where:

C.V: Coefficient of variation

Power requirements:

To estimate the required power during chopping and baling operations, the decrease in fuel level in fuel tank was accurately measured immediately after each treatment. The following formula (2) was used to estimate the engine power, (Hunt, 1983):

$$Power = Fc\left(\frac{1}{60 \times 60}\right)\rho_f \times LCV \times 427 \times \eta_{th} \times \eta_m \times \frac{1}{75} \times \frac{1}{1.36} (KW) \quad \ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Where,

F_c = Fuel consumption, L/h;
P_f = Density of the fuel (0.85 kg/ L for diesel fuel)
LCV = Lower calorific value of fuel (10000 kcaL/kg for diesel fuel);
427 = Thermo - mechanical equivalent, kg. m / kcal,.
η_{th} = Thermal efficiency of engine (40% for diesel engine) .
η_m =Mechanical efficiency of engine (80% for diesel engine).

Energy requirements: Specific energy requirements were estimated by using the following equation (3) :

$$\text{Energy requirements (kW.h/Mg)} = \frac{\text{required power, kW}}{\text{feeding rate, Mg/h}} \quad \ldots\ldots\ldots\ldots(5)$$

The product cost

The costs of chopping and balling processes was based on the initial cost of machine, interested on capital, cost of fuel and oil consumed, cost of maintenance and wage of operator according to the following formula (El-Awady, 1978):

$$C = \frac{P}{h}\left(\frac{1}{a} + \frac{i}{2} + t + r\right) + (1.2 W.S.F) + \frac{m}{144}, \quad (LE/h) \quad \ldots\ldots\ldots\ldots(6)$$

Where:

C = Hourly cost, LE/h.	**P = Price of machine, LE.**
h = Yearly working hours, h/year.	**a = Life expectancy of the machine, h.**
i = Interest rate/year.	**F = Fuel price, LE/L.**
t = Taxes, over heads ratio.	**r = Repairs and maintenance ratio.**
m = The monthly average wage, LE	**1.2 = Factor accounting for lubrications.**
W = Engine power, hp.	**S = Specific fuel consumption, L/hp.h.**

144 = Reasonable estimation of monthly working hours.

The product cost was determined from the following formula:

Product cost, LE/Mg = operating cost, LE/h / machine productivity, Mg/h. ....(7)

RESULTS AND DISCUSSION

Cutting length

As indicated in Fig.1 results showed that by increasing drum speeds from 4.71 to 10.5 m/s, the mean cutting-length was7.88 mm using cutting drum speed of 10.5 m/s, straw moisture content of 12% and feeding rate of 0.9Mg/h. Meanwhile, the maximum mean cutting-length of rice straw 41.8mm was obtained by using cutting drum speed of 4.71 m/s, moisture content of 20 %, feed rate of 1.5Mg/h. The inversely proportion of rice straw cutting length with the drum speed may be due to the increased number of knives impacts against straw per unit time

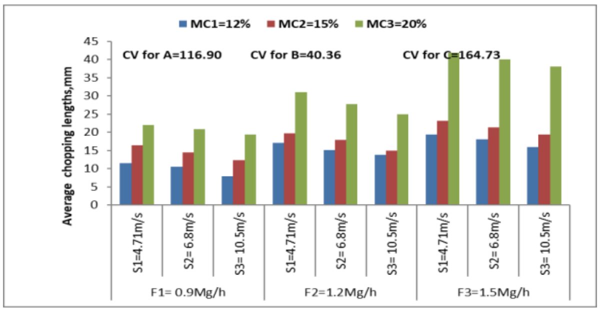

Fig.1. Effect of some chopper operating parameters on mean cutting-length

As shown in table 1,There are significant differences with all the factors (feeding rate, cutting drum speed and straw moisture content) of the study and with the binary interactions and also the triple interaction and the most influential factors on the character of mean cutting lengths is the percentage of moisture content. The lowest coefficient of variation was 40.36% under cutting drum speeds.

Table 1. Analysis of variance of rice straw cutting length

SOV	DF	MS	LSD 5%	LSD 1%	C.V%
A	2.00	576.68**	16.42	22.18	116.90
B	2.00	68.75**	16.42	22.18	40.36
C	2.00	1145**	16.42	22.18	164.73
AB	4.00	0.80**	28.45	38.41	
BC	4.00	0.34*	28.45	38.41	
AC	4.00	77.29**	28.45	38.41	
ABC	8.00	0.61**	49.27	66.54	
Error	27.00	0.10			
	A	15.03	20.25	26.34	
Mean	B	22.43	20.67	18.53	
	C	14.36	17.73	29.54	

A:Feeding rates for rice straw 0.9, 1.2 and1.5 Mg/h.
B:Chopper drum speeds of S1=4.71, S2=6.8 and S3= 10.5m/s.
C:Moisture content for straw rice (dry)Mc1=12, Mc2=15and Mc3=20%.
SOV: sources of variable ,Df: degrees of freedom, MS: variance ,LSD 1%:The least significant difference1% ,LSD 5%:The least significant difference 5% and C.V,%: Coefficient of variance.

Bale density

Fig.2 showed the proportion of baller plunger speed with the bale density. The maximum bale density of 144.6kg/m³ was obtained using plunger speed of 0.45m/s, cutting length<10mmand feeding rate of 1.5 Mg/h. Meanwhile, the minimum bale density of 120.2kg/m³ was obtained using plunger speed of 0.24m/s, cutting length>20.5mmand feeding rate of 3Mg/h. The increasing of bale density is due to increasing the number of strokes of the plunger, small lengths of chopped straw and low feeding rate.

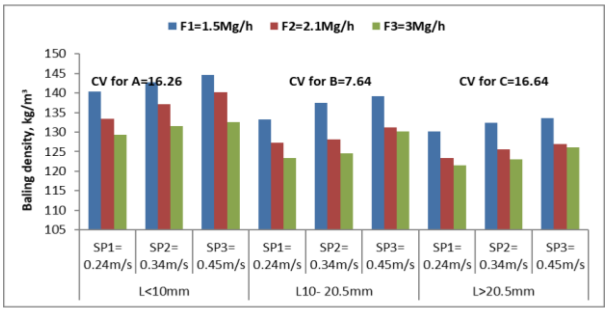

Fig.2. Effect of some baller operating parameters on straw baling density

In table(2) data showed that the study factors(average chopping rice straw lengths, plunger speeds and feeding rates for chopping rice straw)showed significant differences for the characteristics of bale density, There are no significant differences with the binary interactions and also the triple interaction and the most influential factors on the character of bale density is the feeding rates and less coefficient of variation was 7.64% at plunger speeds.

Table 2. Analysis of variance of bale density

SOV	DF	MS	LSD 5%	LSD 1%	C.V, %
A	2.00	456.87**	14.62	19.74	16.26
B	2.00	100.84**	14.62	19.74	7.64
C	2.00	478.56**	14.62	19.74	16.64
AB	4.00	1.73			
BC	4.00	1.10			
AC	4.00	7.75			
ABC	8.00	2.17			
Error	27.00	3.46			
	A	136.88	130.50	126.93	
Mean	B	129.09	131.40	133.82	
	C	137.04	130.37	126.90	

A: Average chopping rice straw lengths <10,10-20.5 and >20.5mm.
B:Plunger speeds of Sp1=0.24, Sp2=0.34 and Sp3=0.45m/s
C:Feeding rates for chopping rice straw F1=1.5, F2= 2.1 and F3=3Mg/h.
SOV: sources of variable, Df: degrees of freedom, MS: variance ,LSD 1%:The least significant difference 1% ,LSD 5%:The least significant difference 5%. and C.V,%: Coefficient of variance.

Size required for bale storage:

Fig.3 Showed the reversely proportion of baller plunger speed with size required bale storage. The minimum size required for storing bales of rice straw of 16.46 m³/fed was obtained using plunger speed of 0.45m/s,, feeding rate of 1.5Mg/h and cutting length<10mm.Meanwhile the maximum size of bale storageof33.2m³/fed was obtained using plunger speed of 0.24m/s, feeding rate of 3Mg/h and cutting length> 20.5mm.The decreasing of size requirements for storing bales is due to increasing the number of strokes of the plunger, small lengths of chopped straw and low feeding rate. The decreasing of size requirements for storing bales are required to provide the place to store the largest amount of bales

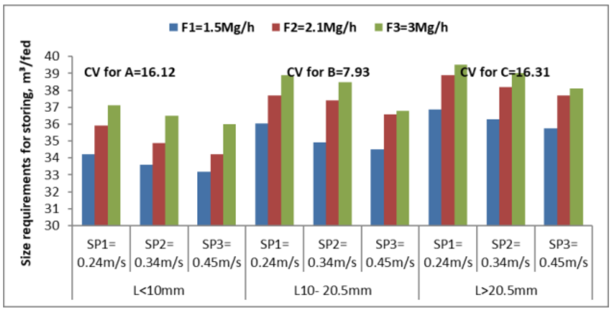

Fig.3. Effect of some baller operating parameters on size of bale storage

Energy requirements of rice straw chopping

Data in Fig. 4 indicated that energy requirements of chopping rice straw related positively and negatively with cutting drum speed and feeding rate, respectively. The lowest energy requirement was8.9 kW.h/Mg at 4.71m/s and 12% moisture content with feed rate of 1.5Mg /h. The decreasing of energy requirements is attributed to increasing of the feeding rate, moisture content and decreasing in the cutting drum speed.

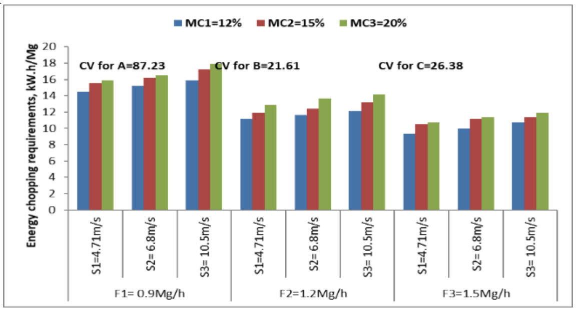

Fig.4. Effect of some chopper operating parameters on energy requirements of rice straw chopping

Energy requirements of baling rice straw

Fig.5 presented the proportion of the energy requirements of rice straw balling with the plunger speed. For the baling process, the lowest energy requirement was 5.67 kW.h /Mg at a compression speed of 0.24 m /s, feeding rate of 3Mg/h and average cutting lengths > 20.5mm.The decreasing of energy requirements of balling is attributed to increasing of the feeding rate and low compression speed.

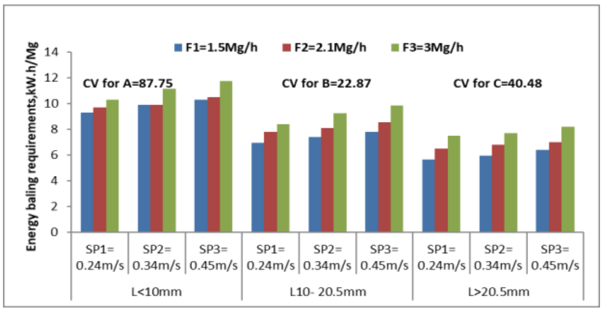

Fig.5. Effect of some baller operating parameters on energy requirements of rice straw baling

Rice straw chopping operating costs

Data in Fig.6show that, the operation costs increased by increasing drum speed. The maximum chopping operating value straw of 129.35 LE/h was recorded at cutting drum at speed of 10.5 m/s and moisture content of 20% Meanwhile, the minimum straw chopping product costs of 79.7LE/Mg was achieved under feeding rate 1.5Mg/h and moisture content of 12%.

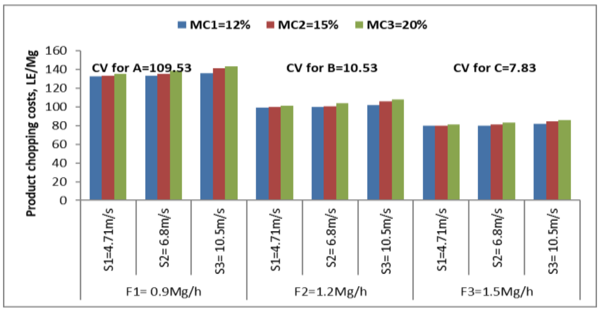

Fig.6. Effect of some chopper operating parameters on chopped straw costs

Rice straw balling costs

Fig.7indicated that by increasing plunger speeds for baller, The operation cost of baling process of 313.46LE/h was recorded at plunger speed of 0.45m/s, under cutting lengths>20.5mm. Meanwhile, the minimum product balling costs of 98.5 LE/Mg was obtained using plunger speed of 0.24m/s under cutting length<10mm and feed rate of 3Mg/h.

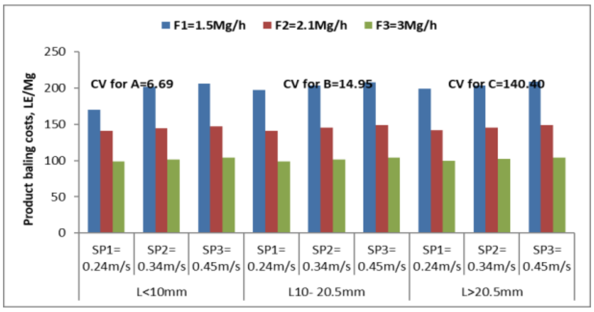

Fig.7. Effect of some baller operating parameters on baling costs.

CONCLUSION

The conclusion of this study can be summarized as follows points:

- The lowest cutting length was achieved at cutting drum speed of 10.5 m/s and moisture content of 12% so as to facilitate its use in several aspects such as animal feeding and paper making.
- Requirements press chopped cutting straw rice save the energy and the costs requirements in treatments.
- Chopping rice straw before baling operation increased the bale density and decreased the size requirements for storing bales.

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سها جمال عبدالحميد

معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية

الهدف من هذا البحث هو دراسة تأثير بعض العوامل علي عملية فرم قش الأرز وعملية كبس القش المفروم من حيث متوسط أطوال القطع علي كثافة البالة والحجم المطلوب للتخزين ومدى توفير الطاقة المطلوبة والتكاليف من كلا العمليتين . المتغيرات بالنسبة لعملية فرم قش الأرز: ثلاث سرعات لدرفيل القطع هى4,71 , 6,8 ,10,5 متر/ثانية وثلاث معدلات تلقيم لقش الأرز هى 0,9 , 1,2 , 1,5 طن/ ساعة و ثلاث محتويات رطوبة لقش الأرز هى12, 15 , 20 %.المتغيرات بالنسبة لعملية تبييل قش الأرز المفروم: ثلاث سرعات ترددية لمكبس لضغط القش المفروم هى0,24 , 0,34, 0,45 متر/ ثانية و ثلاث معدلات تلقيم للقش المفروم هى 1,5, 2,1 , 3 طن/ساعة وأطوال قطع القش المفروم 10, 10– 20,5, >20,5 مماظهرت النتائج ان أقل متوسط لأطوال القطع هى 7,88 ممعند سرعة درفيل القطعمن 10,5 م/ثمع معدل تلقيم القش 0,9 طن/ساعة ومحتوي رطوبي 12%. وكانت أعلى كثافة للبالة هى 144, كجم/م3 تحت سرعة كبس ترددية 0,45 م/ ساعة عند استخدام أطوال القطع <10 مم. وأقل حجم المطلوب للتخزين كانت 16,46 م3/ فدان مع سرعة كبس 0,45 م/ث, معدل تلقيم 1,5 طن/ساعة مع متوسط طول قطع <10 مم. كما أوضحت النتائج ان اقل طاقة مطلوبة لعملية تقطيع قش الأرز 8,9 كيلووات.ساعة/ طن سرعة درفيل القطع4,71 م/ثومحتوى رطوبي للقش 12% بمعدل تلقيم 0,9 طن/ساعة.وكانت اقل طاقة مطلوبة لعملية التبييل هى 5,67 كيلووات. ساعة/طن عند سرعة ترددية للمكبس 0,24 م/ثبمعدل تلقيم 1,5 طن/ ساعة و متوسط طول قطع >20,5 مم . وكانت اقل التكاليف المتحصل عليها بالنسبة لعملية فرم قش الأرز هى79,7 جنيه/طن عند سرعة درفيل القطع4,71 م/ثومحتوى رطوبي للقش 12% بمعدل تلقيم 1,5 طن/ساعة.وكانت اقل التكاليف المتحصل عليها لعملية التبييل هى98,5جنيه/طن عند سرعة ترددية للمكبس 0,24 م/ث بمعدل تلقيم 3 طن/ ساعة أدت عملية فرم قش الأرز قبل عملية التبييل إلى زيادة كثافة البالة وتقليل الحجم المطلوب للتخزين.