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STUDYING SOME MECHANICAL FACTORS AFFECTING CHOPPING SUGAR BEET TOPS INTO SILAGE

Hussein .A.E ., A. O . El Ashhab., and M. A. Ali

SUMMARY

The main objective of the present research is to achieve the effect of, the effective engineering parameters such as chopper types, cutting speed, and knife clearance on frequency length of product, power requirement, chopper output and specific energy to save power and get suitable cut length to chopped sugar beet tops into silage. These investigated parameters have direct effect on the power requirement (kW) and chopper output (Mg/h). Increasing of cutting speed from 18.84 to 23.55 m/s tend to increase power requirement from 20.20 to 22.50 kW, for cylinder cutter heads and from16.0 to 18.90 kW for flywheel cutter heads. While the increasing of knife clearance from 0.5 to 1.5 mm tend to decrease power requirement from 20.2 to 10.3 kW and from16.0 to 11.0 kW for cylinder and flywheel respectively. at moisture content 70 %. The optimum parameters for chopping sugar beet tops into silage, were cutting speed 23.55 m/s and knife clearance 1.5 mm at moisture content 60 % which gave less power required 8.85 kW ,less specific energy 3.54 kW.h/Mg and highest values of output 2.50 Mg/h, for flywheel cutter heads

Key words: chopper, sugar beet tops, silage, Energy, Power requirement.

INTRODUCTION

Sugar beet is one of the most important crops for Egyptian farmers, this is due to the yield for its roots and vines. The cultivated area of sugar beet on the year 2002-2003 were 142638 feddans gave 2.857728 tons sugar beet roots and 71.319 tons beet tops (Agricultural Statistics, 2003). **Naylor and Ralston (1991)** concluded that, because of the laxative effect of sugar beet tops, the daily amount should be limited to about 3kg calf and 12 kg/cattle. Also, they reported that the moderate amount of (Ca) element in sugar beet tops bounded with oxalic acid resulted in unavailability of (Ca) to the animals. **Abd el-Halim (1998)** found that sugar beet tops (SBT) were transported in trailers to the experimental station and there after the tops were spread over a layer of rice straw and were left for 2-3 days to be wilted to diminish the moisture content to about 65-70%, before making silage. Limestone was added at the rate of 0.5% to raise the Ca content of the silage produced. The quality of silage describe as shown in table (1).

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Table (1): The quality of silage

Criteria On DM basis*	Silage quality	
	Good quality	Bad quality
PH	< 4.5	> 5.1
Butyric acids %	< 0.4	> 1.4
Laclic acid %	> 1.5	< 0.5
NH3-N (% of total N)	< 10.0	> 21.0

Yumnam and Singh (1991) stated that blade angle influence the energy requirement for rotary blade, the minimum power requirement was observed at blade angles between 25^{o} and 30^{o}, that most preferable bevel angle between $10^{o} - 20^{o}$. **Chattopadhyay and Pandey (2001)** found that tip speed of the cutter / blower(40 m/s) was an optimal flail tip velocity to provide adequate blowing of maize. Therefore, the 0.41m diameter flail mechanism was required to rotate at least 1800 rpm. **Zhang *et al.*, (2003)** concluded that specific energy for the flail cutter / blower ranged from 2.0 to 4.7 kW.h /Mg DM for moisture content 60-70%.and (0.51 to 1.2 kW.h /Mg) for flail tip speed ranged from 38.4- 45.6 (m/s). Moisture content of silage and flail speed, were highly correlated to specific energy, but the number of flails was not. .**ASAE S472 (1998)** theoretical length of cut (TLOC) shall expressed in mm/knife.

$$TLOC = \frac{\pi \times (D_1 \times N_1 + D_2 \times N_2) / Z}{N \times K}$$

Where:

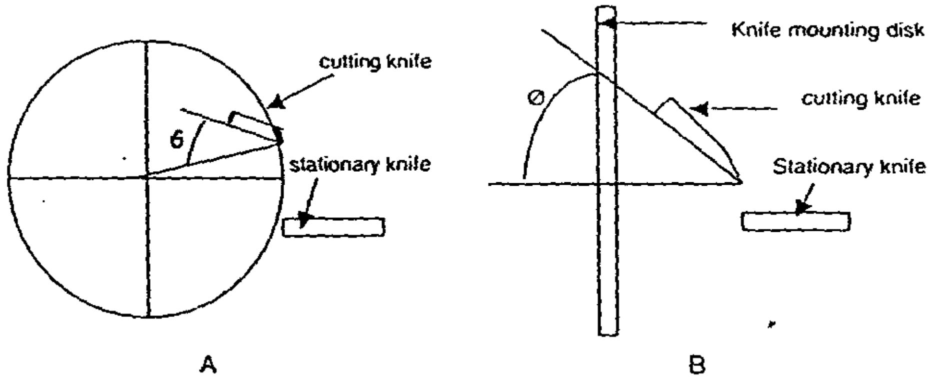
D_1 is the supper rear feed roll effective feeding diameter, mm;
D_2 - lower rear feed roll effective feeding diameter, mm;
N_1 - super rear feed roll speed, r/min;
N_2 - lower rear feed roll speed, r/min;
N - cutter head speed, r/min;
K - number of cutter head knives per revolution passing by Fixed point.
Z - number of feed rolls used in TLOC Z = 1 or 2

Ghulam, and Finner (1981). Measured the length of chopped part as :

$$L = TLC / \sin\theta$$

Where: L is the length chopped piece (mm;)
TLC - theoretical length of cut;
θ - rake angle.

The knife rake angle (θ) of cylinder cutter heads: is the included angle between the knife leading surface at the cutting tip, and a radial line passing through the knife cutting tip. The knife rake angle of flywheel cutter heads: is the included angle between the knife leading surface at the cutting tip and a line parallel to the cutter head axis of rotation. As shown in (Fig. 1).



Fig(1): (A) The knife rake angle, Ø of cylinder cutter heads

(B) The knife rake angle, Ø of Flywheel cutter heads.

The aim of this research study was to evaluate some operating parameters such as (moisture content, cutting speed and knife clearance) affecting on the chopper performance, and power requirements.

MATERIAL AND METHODS

The main experiment was carried out at the Animal Production Research Station of Sides – Beni-Sweif Governorate, during 2002-2003.

The characteristics of the PTO driven choppers used in the study IS shown in Table 2.

Table (2). Specifications of choppers.

Item	Cylinder cutter heads	Flywheel cutter heads
Manufacture	Local manufacture	Local manufacture
Power ,HP (kW)	20 (14.6)	16 (11.6)
No of cutting knifes	4	3
Cutting knife length, cm	30	55
Capacity green forage, Mg/h	2.5	2.0
Dry crop residual Mg/h	0.75	0.70
Weight ,kg	300	250
Cutting drum Speed, rpm	1500	1500
Feeding drum speed rpm	110	150

the drying oven at 105 c^0 for 24 h .Moisture content was then computed as follow:

$$Mc\ (W\ b\%) = \frac{\text{weight of wet sample - weight of dry sample}}{\text{weight of wet sample}} \times 100$$

where: Mc (W b %) is the moisture content in wet basis, %

- **Chopper evaluation:**

The criteria used to evaluate tested choppers were capacity, chopper efficiency and power consumption. Chopper capacity (Mg/h), Chopping efficiency and the particle length distribution were determined via **ASAE standard S424.Method of determining and expressing particle size of chopped forage materials by screening**. A set of sieves with opening sizes 25 ,38, 44 and 57 mm were used .

As a result of sieving , the material finance was classified into grades. Fine particles that pass through 25 mm sieve, middle size materials that pass through 38 mm sieve and course materials that pass through 44 mm sieve. Other materials sieved between the 57mm and 44 mm sieves was considered Lamp.

The mean weight length (MWL) was computed as follow:

$$(MWL) = \Sigma(s_1w_1 + s_2w_2 + s_3w_3 + s_4w_4) / \Sigma w$$

Where:

S_1 S_2 S_3 , S_4. sieve opening size

w_1 w_2 w_3 , w_4. weight screening materials for each sieve

- **Power requirement** (kW): The choppers Powered by the tractor PTO.

The power required for chopper operation (EP) was calculated as follow according to **(Nasr, 1985)**

EP=3.163 Fc, (kW)

Where: Fc is the fuel consumption, L/h.

- **Energy consumption (kW.h / Mg):**

The energy consumed for chopping beet tops was calculated as follow:

$$\text{Energy consumption} = \frac{\text{Power consumption (kW)}}{\text{Capacity of forage chopper (Mg/h).}}$$

RESULTS AND DISCUSSION

This study was devoted to evaluate performance of two types of chopper, namely; cylinder cutter heads and flywheel cutter heads. Parameters such as cutting speed, and knife clearance were tested in cutting sugar beet tops. Evaluation criteria such as power requirement, chopper output and energy consumption were determined.

- **Chopper performance:**

The machine data concerning, cutting speed, size reduction and MWL of the two types of choppers, flywheel and cylinder cutter heads were shown in Table (3) and Figure (2).The frequency of cut lengths were (38%, 27%, 18% and 17%) and (28%, 22%, 13% and 37%) at the different size of sieve hole sizes (<25mm, 25-38, 38-44 and 44-57 mm) for both flywheel and cylinder cutter heads choppers, respectively at cutting speed 23.55 m/s.

Table (3): size reduction and MWL for sugar beet tops after chopping.

Type Of Chopper	Cutting speed, m/s	Cut lengths distribution %				MWL, mm	ILC, mm	$\frac{MWL - ILC}{ILC} \times 100$, %
		<25 mm	25-38 mm	38-44 mm	44-57 mm			
Flywheel	18.84	40	25	20	15	33	32	4.53
	21.19	42	23	22	13	34	32	5.15
	23.55	38	27	18	17	34	32	5.46
Cylinder	18.84	30	23	14	33	37	32	16.25
	21.19	28	20	15	37	37	32	16.78
	23.55	28	22	13	37	38	32	18.81

- **Effect of cutting speed and knife clearance on chopper output Mg/h.**

The productivity (chopper output Mg/h) of the two types of choppers, increased by increasing knife clearance as shown in Tables (4-5) and Fig (3). The maxium chopping output was 2.13 Mg/h, for cylinder machine and 2.6 Mg/h for the flywheel cutter heads machine . These results were achieve at knife clearance 1.5 mm ,cutting speed 23.55 m/s and moisture content 70%. At 60% moisture content, the productivity was 2.05Mg/h for the cylinder machine and 2.5 Mg/h for the flywheel cutter heads machine .

Fig (3) show that more productivity of flywheel than the cylinder types, this may be because of the increasing knives effecting cutting length. (knives effective cutting length = knife length(cm) x number of knives on cutter heads).

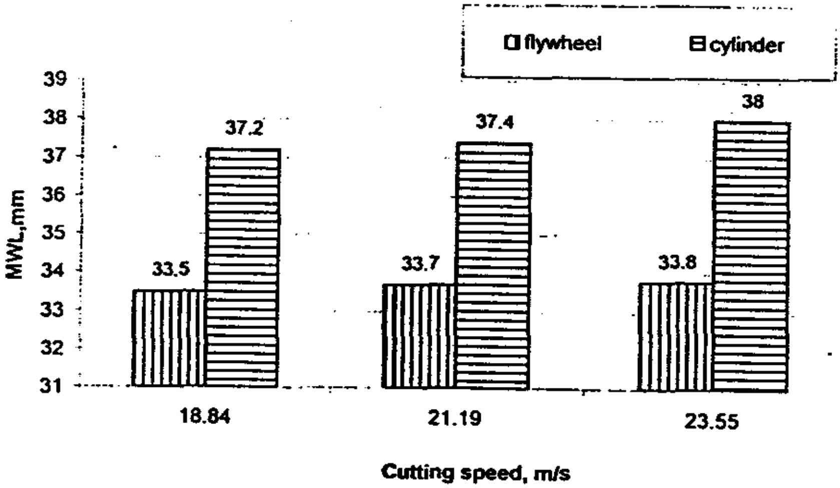


Fig (2): Effect of cutting speed and type of chopper on the mean weight length.

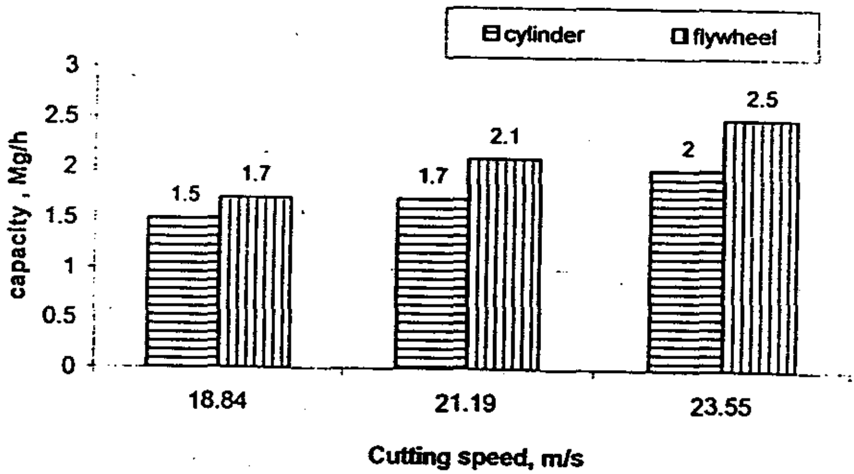


Fig (3): Effect of cutting speed and type of chopper on machine capacity.

Table(4): Effect of knives clearances and cutting speed on chopper output, Mg/h at moisture content 70 %.

Type of chopper	Cutting speed, m/s	Knife clearance, mm.			
		0.5	0.8	1.1	1.5
		Chopper output, Mg/h			
Cylinder	18.84	1.41	1.51	1.56	1.61
	21.19	1.61	1.73	1.49	1.85
	23.55	1.85	1.99	2.07	2.13
Flywheel	18.84	1.52	1.95	1.71	1.79
	21.19	1.94	2.69	2.17	2.22
	23.55	2.25	2.42	2.52	2.63

Table(5): Effect of knives clearances and cutting speed on chopper output, Mg/h at moisture content 60 %.

Type of chopper	Cutting speed, m/s	Knife clearance, mm.			
		0.5	0.8	1.1	1.5
		Chopper output, Mg/h			
Cylinder	18.84	1.37	1.46	1.51	1.55
	21.19	1.57	1.67	1.44	1.78
	23.55	1.81	1.92	2.0	2.05
Flywheel	18.84	1.49	1.89	1.65	1.7
	21.19	1.94	2.6	2.1	2.13
	23.55	2.2	2.34	2.43	2.5

- **Effect of cutting speed and knife clearance on power requirement**

The power requirement (kW) was calculated by recording fuel consumption L/h for the tractor during the chopping operation. Tables (6-7) and Figures.(4 - 7) showed that the maximum power required was22.5 kW for the cylinder chopper, at knife clearance 0.5mm and cutting speed 23.55 m/s. Increasing cutting speed from 18.84 to 23.55 m/s tend to increase power requirement (20.20 to 22.50 kW), for the cylinder chopper and (16.0 to 18.90 kW) for the flywheel chopper. Increasing knife clearance from 0.5 to 1.5 mm decrease power requirement from (20.2 to 10.3 kW), and from (16.0 to 11.0 kW) for cylinder and flywheel chopper respectively. at moisture content 70 %.

The results also show that increasing moisture content from 60 to70% increased the power and energy required for chopping sugar beet. as shown in tables .(from 4 to 9)

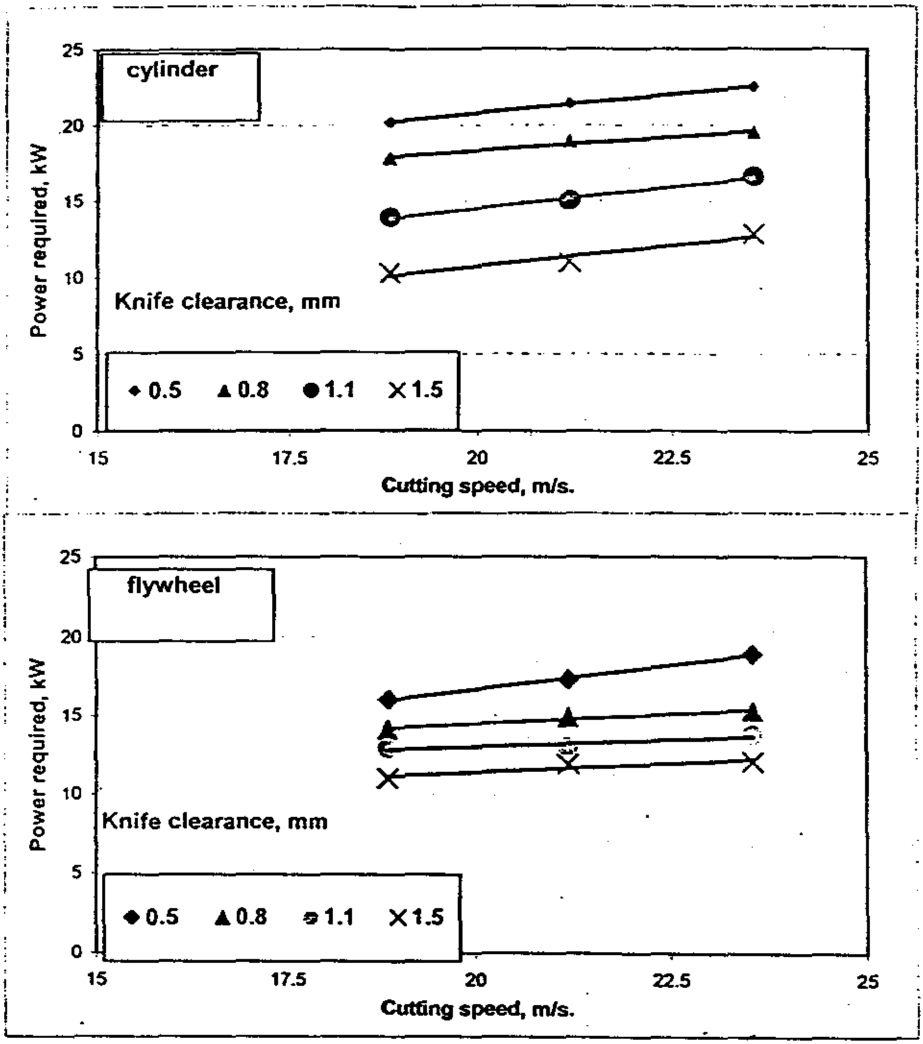
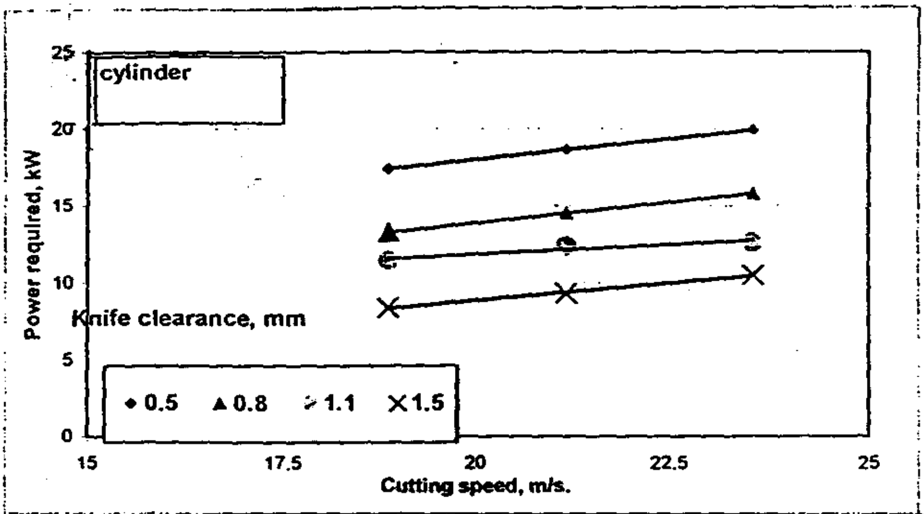


Fig (4): Effect of cutting speed and chopper type on power requirements at m.c 70%.



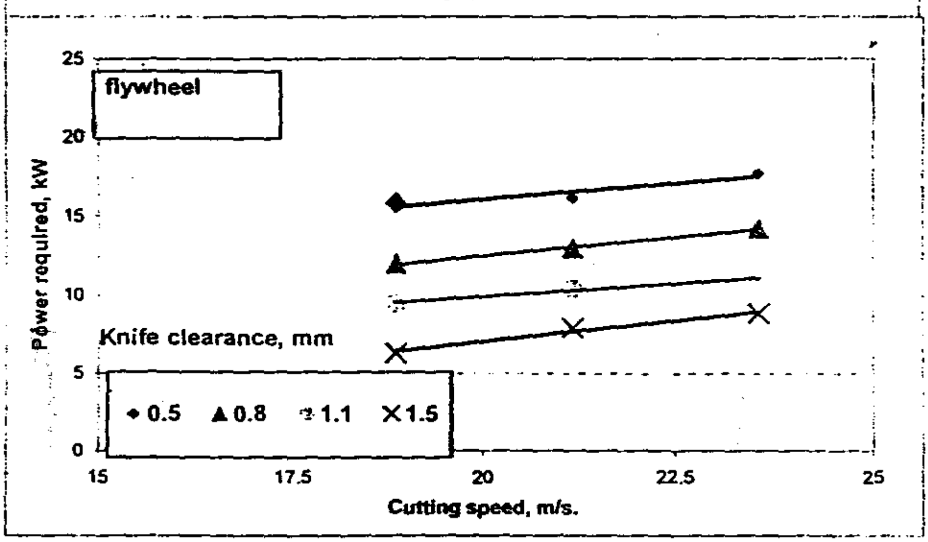


Fig (5): Effect of cutting speed and chopper type on power requirements at m.c 60%.

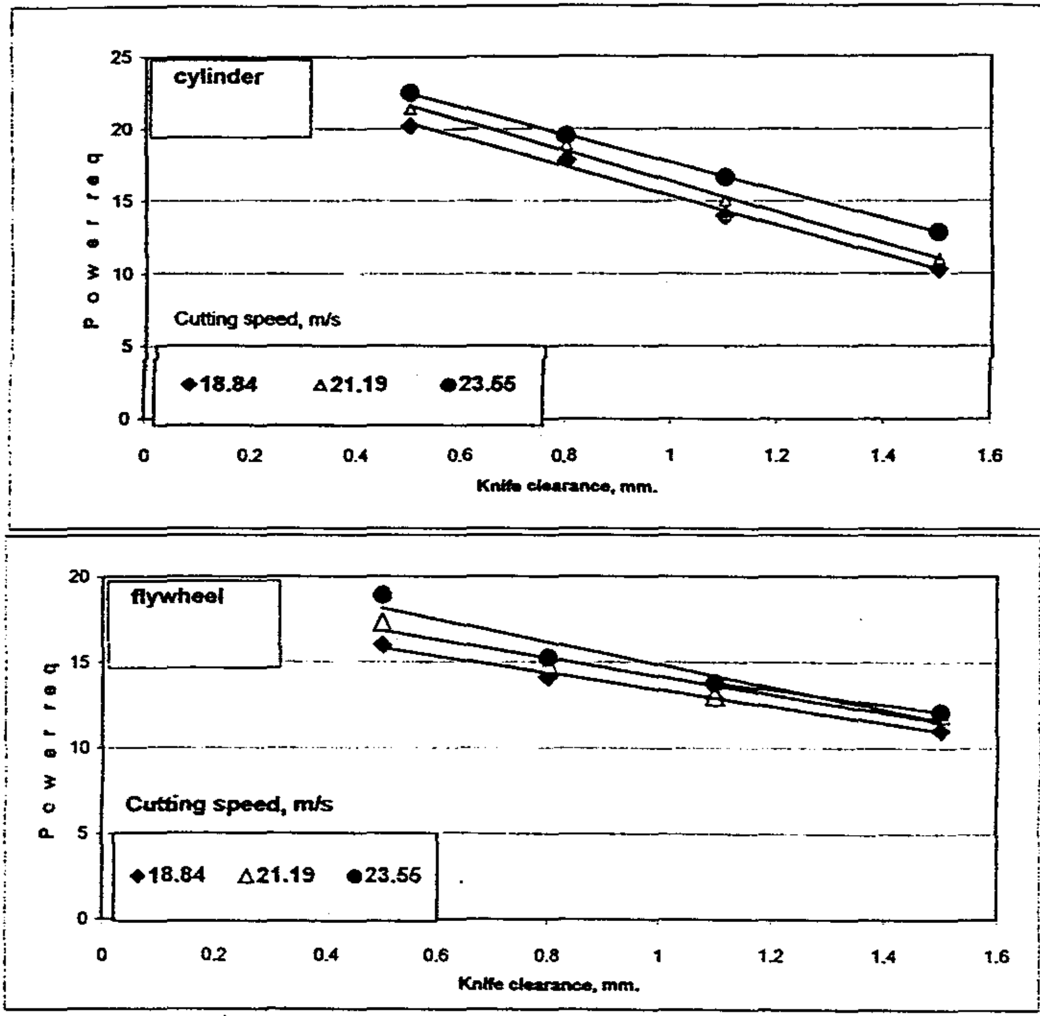


Fig (6): Effect of knife clearance and chopper type on power requirements at m.c 70%.

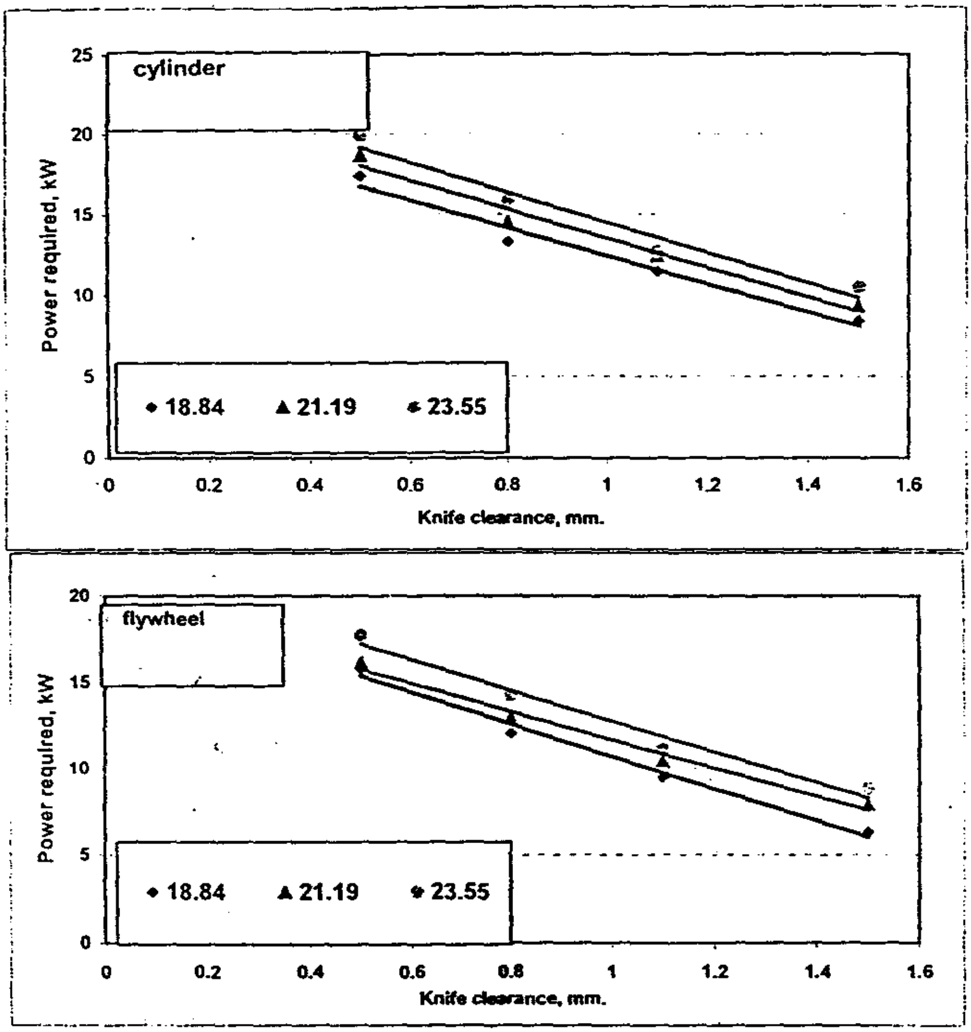


Fig (7): Effect of knife clearance and chopper type on power requirements at m.c 60%.

Table 6: Effect of the knife clearance (mm) and the cutting speed (m/s) on the Power requirement (kW) for the two types of choppers used at moisture content 70 %.

Type of chopper	Cutting speed, m/s	Knife clearance, mm.			
		0.5	0.8	1.1	1.5
		Power required, kW			
Cylinder	18.84	20.20	17.83	13.95	10.30
	21.19	21.40	18.90	15.00	11.00
	23.55	22.51	19.51	16.63	12.85
Flywheel	18.84	16.00	14.10	12.91	11.00
	21.19	17.30	14.90	13.00	11.95
	23.55	18.90	15.30	13.80	12.10

Table (7): Effect of the knife clearance (mm) and the cutting speed(m/s) on the Power requirement (kW) for the two types of choppers used at moisture content 60 %.

Type of chopper	Cutting speed, m/s	Knife clearance, mm.			
		0.5	0.8	1.1	1.5
		Power required, kW			
Cylinder	18.84	17.38	13.27	11.43	8.37
	21.19	18.65	14.54	12.38	9.30
	23.55	19.90	15.80	12.64	10.48
Flywheel	18.84	15.80	12.01	9.48	6.32
	21.19	16.12	12.96	10.43	7.90
	23.55	17.70	14.22	11.06	8.85

- **Effect of cutting speed and knife clearance on Specific Energy (kW.h /Mg).**

The energy consumption for chopper operating (kW.h/Mg) was calculated by using the following formula. As shown in tables (8and9) .

$$\text{Energy consumption} = \frac{\text{Power required (kW)}}{\text{Capacity of chopper (Mg/h).}} \quad \text{(kW.h /Mg)}$$

Table (8): Effect of the knife clearance (mm) and the cutting speed (m/s) on the specific energy (kW.h/Mg) for the two types of choppers used at moisture content 70%

Type of chopper	Cutting speed, m/s	Knife clearance, mm.			
		0.5	0.8	1.1	1.5
		Specific Energy (kW.h/Mg)			
Cylinder	18.84	14.40	11.80	8.90	6.39
	21.19	13.30	10.90	10.0	5.90
	23.55	12.10	9.80	8.32	6.03
Flywheel	18.84	10.50	7.20	7.54	6.21
	21.19	8.87	5.50	5.99	5.40
	23.55	8.40	6.30	5.45	4.60

Table (9): Effect of the knife clearance (mm) and the cutting speed (m/s) on the specific energy (kW.h/Mg) for the two types of choppers used at moisture content 60%

Type of chopper	Cutting speed, m/s	Knife clearance, mm.			
		0.5	0.8	1.1	1.5
		Specific Energy (kW.h/Mg)			
Cylinder	18.84	12.68	9.0	7.55	5.40
	21.19	11.8	8.7	8.59	5.22
	23.55	10.9	8.22	6.39	5.11
Flywheel	18.84	10.6	7.54	5.74	3.71
	21.19	8.3	4.95	4.96	3.70
	23.55	8.09	4.25	4.58	3.54

The optimum parameters for chopping sugar beet tops into silage, were cutting speed 23.55 m/s and knife clearance 1.5 mm at moisture content 60 %.At this levels the maximum productivity2.50 Mg/h, minimum power required 8.85 kW and lower specific energy 3.54 kW.h/Mg were achieved by flywheel cutter heads type. While for cylinder cutter heads the optimum parameters were, cutting speed 23.55 m/s and knife clearance 1.5 mm at moisture content 60 %. Which gave productivity 2.05 Mg/h, power required 10.48 kW and specific energy 5.11 kW.h /Mg.

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الملخص العربي

دراسة بعض العوامل الميكانيكية المؤثرة على فرم عرش بنجر السكر

د. أحمد أمام حسين* - د. احمد أسامة محمد الأشهب* - د. مصطفى عبد الكريم علي*

يعتبـــر محصول بنجر السكر من المحاصيل الاستراتيجية والاقتصادية عالية العائد مقارنة بالمحاصيل الشتوية الأخرى، ليس فقط لإنتاج السكر بل لأنها تنتج كميات كبيرة من عروش بنجـــر السكر الطازجة في موسم حصاد المحصول ولا يستفاد منها حيث تترك في الحقول مسببة تلوثا للبيئة نتيجة لتعفنها وانتشار الآفات الزراعية. ويبلغ زمام مساحات بنجر السكر فـــي مصر ١٤٢٦٣٨ ألف فدان (موسم ٢٠٠٢ - ٢٠٠٣) وتبلغ إنتاجية بنجر السكر منها ٢,٨٥٧,٧٢٨٥ طن وتعطي ٧١,٣١٩ طن من العروش الخضراء. لذا يجب الاستفادة منها أسوة بما يحدث في جميع البلاد المنتجة لمحصول بنجر السكر. وتستخدم هذه العروش أما بنشـــرها وحرثها في التربة كسماد عضوي أو استخدامها في التغذية الحيوانية على صورة سيلاج.

لذلك كان الهدف من البحث :

اختبار بعض العوامل الميكانيكية : مثل نوع درفيل القطع - سرعة القطع وخلوص سكينة القطع وأثر هذه العوامل على كل من :

١. طول القطع لناتج فرم عرش بنجر السكر ٢. القدرة اللازمة لعملية الفرم

٣. الطاقة المستهلكة بالكيلو وات ساعة/طن ٤. إنتاجية الآلة بالطن في الساعة

والاستفادة من ذلك في أستخدام عرش بنجر السكر في تغذية الحيوانات على صورة سيلاج وبـــذلك يمكـــن حمايـــة البيـــئة من التلوث الناتج عن ترك هذه المخلفات في الحقل وعلى المصـــارف وما تصبب من أضرار للبيئة. وزيادة العائد الاقتصادي من المحصول بتدوير عرش البنجر ليصبح ذو قيمة اقتصادية يعود بالمال على المزارع.

وقد أوضحت النتائج ما يلي :

١. زيادة سرعة القطع ونقص خلوص سكينة القطع أدى الى زيادة الطاقة المطلوبة.

٢. أنسب سرعة قطع للسكينة كانت ٢٣,٥٥ م/ث مع قدرة مستهلكة ٨,٨٥ كيلو وات مـــع خلوص ١,٥مم. وكانت نسبة رطوبة المخلف ٦٠% وذلك عند استخدام آلة التقطيع ذات السكينة المستقيمة (Flywheel cutter head).

٣. زيادة سرعة القطع من ١٨,٨٤ الى ٢٣,٥٥ م/ث أدى الى زيادة القدرة المطلوبة مـــن ٦,٣٢ الى ٨,٥ كيلو وات ونقص طـــول المخلف المقطوع من ٣٤مم الى ٣٣ مم.

٤. أوضحت النتائج أنه عندما تقل نسبة رطوبة المخلف تقل بالتالي القدرة المطلوبة للتقطيع.

* باحث بمعهد بحوث الهندسة الزراعية.