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STUDYING SOME OPERATIONAL FACTORS FOR AGRICULTURAL WASTE SHREDDER (BAERCAT) AND THEIR IMPACT ON SOME TECHNICAL INDICATORS OF THE MACHINE

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ABSTRACT

This study aimed to evaluate the performance of the BAERCAT shredder during shredding some farm waste to reduce its size and produce unconventional animal feed. A split-split plot design used to implement the experiment with three factors, first factor was the cutting knife type with two levels serrated edge and a smooth edge, the second factor was feeding speeds with two levels (5.5 and 9.5 rpm), and the third factor was types of crop waste with two levels (palm fronds and corn stalks) with three replicates. The cutting speed was fixed during the experiment (1450 rpm). Some machine performance indicators were studied, including machine productivity, total required power, specific energy and Power to accelerate the forage. The results indicated that the knife with a serrated edge achieved the highest productivity (109.60kg/h), the lowest total required power (7.00kw), and the lowest specific energy (0.0647kwh.kg^{-1}). The lowest total required power was achieved (7.20 kw). The lowest Power to accelerate the forage (0.043kw) at feeding speed (5.5 rpm), while the type of crop (corn stalks) gave the lowest total power required (7.00 kw), the lowest Power to accelerate the forage (0.050 kw), and the lowest specific energy (0.0687kwh.kg^{-1}), Increasing the feed speed increased the machine's productivity and the total required power, The highest machine productivity values, the lowest total power required, fuel consumption, specific energy using a knife with a serrated edge.

Keywords: machine productivity, specific energy, agricultural waste, forages.

دراسة بعض العوامل التشغيلية لالة تقطيع المخلفات الزراعية نوع (BAERCAT) وتأثيرها على بعض المؤشرات الفنية للالة

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الخلاصة

هدفت هذه الدراسة إلى تقييم أداء آلة التقطيع (BAERCAT) أثناء تقطيع بعض مخلفات المزرعة لتقليل حجمها وانتاج اعلاف حيوانية غير تقليدية. تم أستخدام تصميم الالواح المنشقة المنشقة لتنفيذ التجربة بثلاث عوامل، العامل الاول هو نوع سكين القطع بمستويين, حافة مسننة و حافة ملساء, والعامل الثاني هو سرعات التغذية بمستويين (5.5 و

* **This article is taken from the first researcher's master's thesis.**

(9.5rpm) وأماالعامل الثالث فهوانواع مخلفات المحاصيل بمستوين (سعف النخيل وسيقان الذرة) وبثلاث مكررات. تم تثبيت سرعة القطع أثناءالتجربة (1450 rpm). تم دراسة بعض مؤشرات اداء الالة ومنها انتاجية الالة, والقدرة المطلوبة الكلية , والطاقة النوعية, والقدرة المطلوبة لدفع الاعلاف. اشارت النتائج الى ان السكين ذات الحافة المسننة حققت اعلى انتاجية وكانت (109.60 kg/h) واقل قدرة مطلوبة كلية (7.00 kw) واقل طاقة نوعية ($kwh.kg^{-1}$ 0.0647). وتم تحقيق اقل قدرة مطلوبة كلية (7.20 kw) واقل قدرة لدفع الاعلاف (0.043 kw) عند سرعة تغذية (5.5rpm). بينما نوع المحصول (سيقان الذرة) اعطت اقل قدرة مطلوبة كلية (7.00 kw) واقل قدرة مطلوبة لدفع الاعلاف (0.050 kw) واقل طاقة نوعية ($0.0687\ kwh.kg^{-1}$). زيادة سرعة التغذية أدت لزيادة أنتاجية الماكينة والقدرة المطلوبة الكلية, كان أعلى قيم انتاجية الالة وأقل قدرة مطلوبة كلية وأستهلاك للوقود و طاقة نوعية بأستخدام السكين ذات الحافة المسننة.
الكلمات المفتاحية: انتاجية الالة، الطاقة النوعية، مخلفات زراعية، الاعلاف.

INTRODUCTION

Field crop residues are considered one of the most important problems facing Iraqi farmers, and they are increasing over time. In Iraq, millions of tons of waste are produced annually due to its environmental diversity and the size of its agricultural area. It is estimated at about 20 million tons of waste annually, and only a small part of it is used **(Ali & Flayeh, 2023)**.In many places, unscientific and primitive methods are used to dispose of these wastes. One of these methods is burning it, which results in economic losses, as well as the emission of warming gases (CO2, N2O, CH4) and air pollutants (CO, NH3, NOX, SO2, NMHC and volatile organic compounds), which have harmful effects on human health and the environment. **(Koul, *et al*., 2022), (Jain, *et al.*, 2014).** Under the current circumstances, the world is striving to manage agricultural waste and add economic and environmental value to it **(Ghobashy, *et al.*, 2023).** Plant and animal wastes are used to increase the stability of soil aggregates and improve their structure (Abdulridha & Essa, 2023)**.** Notice **(Armsh & Ali, 2023)** There is a clear decline in the rates of area cultivated with fodder crops and production. Livestock production is characterized by a clear deficiency in the diet, especially grasses, good quality pastures and green forages. The availability of these forages is necessary to feed livestock **(Saeed & Mohammed, 2017).** Livestock is considered a basic and important source of support for the economy. It is also considered a national wealth that contributes to enhancing food security (**Al-Lazzawy & Al-Mashadany, 2017).** Since forage represents 70-75% of the total production cost, finding alternatives to forages is an ongoing endeavor, which may make forage costs lower **(Al-Aboudi & Hamodi , 2023).** To reduce production costs and import rates, the use of local non-traditional forage s instead of imported ones is encouraged **(Jasim & AI-Obaidi, 2022).** Farmers must cover their nutritional needs for ruminants with natural plants only, so dates and date by-products are used to feed livestock, such as palm fronds, petioles, and date pits **(Kahraman, *et al.*, 2022).** Rough fodder is considered the most nutritious material for ruminant animals **(Alsamraee, *et al.*, 2014), (Akhgar, *et al.*, 2019)**. In order to provide more fodder for ruminants, confront the lack of natural pastures in dry and semi-arid areas, and benefit from non-traditional feed such as corn crop waste, therefore recycling agricultural waste is considered a very important matter **(Al-Mamouri & Al-Ani, 2024).**Many studies have concluded that it is necessary to exploit the remains of some industrial and agricultural crops, given the scarcity of natural pastures and places designated for growing green fodder **(AL-Samaraae, *et al.*, 2008)**. The corn crop is considered an important source of nutrition for humans and animals, as well as the production of biofuel **(Dhannoon, *et al.*, 2021)**. It is considered the third most important crop after wheat and rice (**(Al-Hilfy & Al-Temimi, 2017)**. Date palm fronds were used sustainably to replace imported barley straw in feeding Friesian and Holstein cows. The results of feeding experiments showed that milk production, milk composition and live weight gain of cows fed on date palm fronds or barley straw did not differ significantly. Therefore, it can be concluded that palm fronds-which Sustainable local resource treated as waste-it can be used as an acceptable alternative to expensive imported barley straw in cow feed **(El-Mously, *et al.*, 2023)**. Designing the best system for the agricultural waste cutting machine to obtain the best final product, as well as preparing balanced feed in the least time and optimizing resources **(Limaymanta, *et al*., 2021)**. The performance of agricultural waste shredders has been studied by many researchers to reduce the size of waste such as coconut leaves **(Kumar & Kumar, 2015).** As the stem diameter increases, the energy needs and cutting force increase **(Megahed, *et al.*, 2015)**. The influencing factors during the waste cutting process are related to cutting performance, machine specifications, and plant material properties **(Habib, *et al.*, 2002)**. The fuel consumption, machine productivity, and cutting efficiency are all affected by the cutting speed, the knife edge angle, and the clearance distance, according to the results obtained **(Suliman, *et al.*, 2010)**. The operational characteristics of cutting blades having different designs, edge geometries and impact angles were studied **(Momin, *et al*., 2017)**. The shape of the cutting edge and the kinematics of the cutting process. Various material deformations occur during the process of cutting plants when the cutting knife penetrates the material when its strength increases and separates it **(El-Hanfy & Shalby, 2009).** When the feeding rate of rice and barley straw was increased, the energy consumption rate decreased .As for rice, the rate of energy consumption decreased from 9.84 to 8.36 kw.h at a rate of 1.5 to 0.18 kg/h, while for barley, it decreased from 8.36 to 7.1 kw.h **(Elnaggar & Saleh, 2014)**. According to the studies conducted, the cutting angle should range between 30-40 degrees in the forage cutting blades **(Mashhadani & Al-Badri, 2023).** Agricultural residues is considered one of the most important problems facing agriculture in Iraq, in addition to the environmental pollution it causes when treated incorrectly, as well as the high prices of imported fodder and the need to fill the shortage in livestock fodder, but with the use of chopping machines and an explanation of their importance and optimal use methods, for this reason care is taken The current study measured and calculated the performance, productivity, and energy requirements of the shredding machine, as well as testing and evaluating it to be suitable for use in shredding agricultural residues and producing unconventional feed that contributes to reducing the prices of imported feed.

MATERIALS AND METHODS

The experiment was carried out in the Textile Agriculture Laboratory/Al-Rashid Municipality/Baghdad Municipality during November 2023. Some technical factors for the agricultural waste cutting machine were studied. The machine model CH922DH, company name Bearcat, USA Figure (1) and the illustration diagram Figure (2).

Figure (1): waste cutting machine.

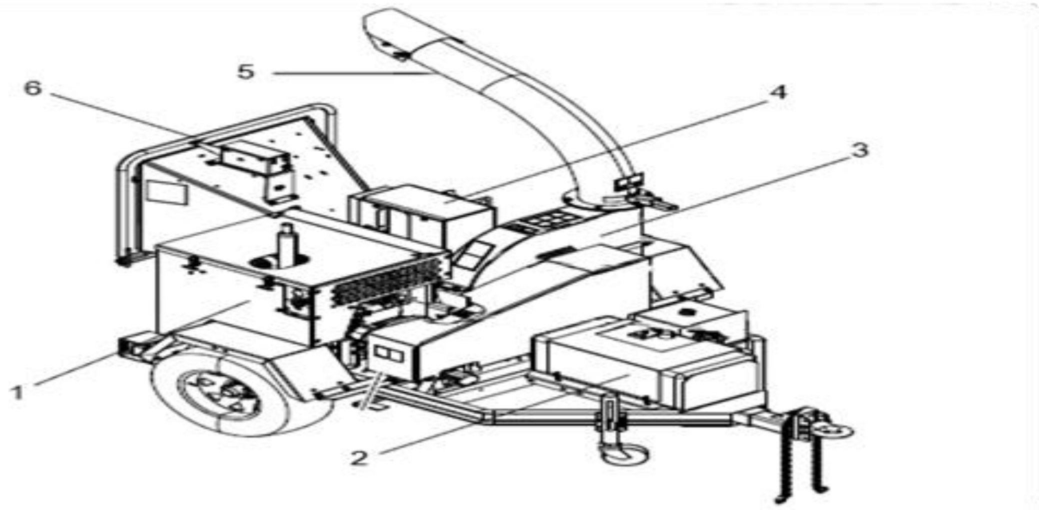

Figure (2): Schematic of the waste cutting machine.
1- Engine. 2- Fuel tank. 3- Shredder cylinder location. 4- Feed cylinder location. 5- Discharge pipe 6- Feed hole.

The cutting unit consisteds of a dynamically balanced disc with a diameter of 76 cm, a thickness of 3.2 cm and a weight of 125 kg, which produces a corona cutting force at a rotational speed of 1450 rpm. Mounted on the cutting disc are four reversible, heat-treated steel cutting knives. The dimensions of each knife were (length 12.7 cm, width 10.2 cm, thickness 1.3 cm) and a cutting edge at an angle of 45 degrees. Two types of knives were used to conduct the experiment, with a smooth edge and a serrated one, as shown in Figure (3).


A


B

Figure (3): A- knife with a serrated edge B- knife with a smooth edge.

The feeding system is independent hydraulic and contains a feeding cylinder with a diameter of 38 cm and 10 blades. The feeding opening was 23 x 23 cm and the length of the feeding table was 96.5 cm.

The following parameters were used in implementing the experiment to measure the machine's performance in terms of:
- Cutting knives cylinder speed (1450 rpm)
- Two types of cutting knives (smooth edge and serrated edge)
- Two feeding speeds (5.5 and 9.5 rpm)
- Two types of agricultural waste (corn stalks and palm fronds). The moisture content of corn stalks was 56%, while that of palm fronds was 34%.

10 samples of crop residues (corn stalks and palm fronds) were taken to study some of the physical properties mentioned in Table (1).

Table (1): Specifications of corn stalks and palm fronds.

sequence	Corn stalks				Palm fronds			
	Length cm	weight gm	Min. stem Diameter cm	Max. stem Diameter cm	Length cm	weight gm	Min. stem Diameter cm	Max. stem Diameter cm
1	178	231	0.88	2.49	341	832	0.47	7.48
2	182	381	0.65	3.14	297	685	0.37	6.95
3	175	355	0.93	2.79	293	390	0.33	6.46
4	169	155	0.65	2.09	261	373	0.36	5.54
5	174	313	0.97	2.90	329	620	0.24	6.48
6	183	177	0.93	3.14	356	820	0.39	8.02

7	172	246	0.88	2.45	321	905	0.41	7.37
8	179	321	0.64	2.35	305	670	0.40	6.56
9	168	107	0.85	2.12	346	614	0.22	6.63
10	162	142	0.58	1.65	315	620	0.38	7.16
Mean	1742	242.8	0.796	2.512	3164	6529	0.357	6.865

Calculating the studied characteristics to evaluate the machine's performance:
Productivity (kg.h^{-1}):

Three air-dried samples of agricultural waste (about 2 kg each) were taken and fed to the machine for each sample. A precise digital stopwatch with an accuracy of 0.1 s was used to collect the cutting material output and record the corresponding time. Average machine productivity was then determined by weighing the resulting material. Machine productivity was calculated using the following equation: **(Al-Gezawe, *et al*., 2016), (ARIF & ELAIWA, 2009).**

$$P = \frac{W}{T} \times 3600$$

Where: P: Machine productivity (kg.h^{-1}). W: Plant weight (Kg). T: Time (sec).

Required total power (KW):

The following formula was used to determine the engine power required to operate the agricultural waste cutting machine **(Abdrabo, *et al.*, 2014), (Hunt, 1995):**

$$EP = \frac{FC \times Pr \times L.C.V \times 427 \times \eta_m \times \eta_{th}}{3600 \times 75 \times 1.36}$$

Where: EP: Power requirements consumption during the chopping operation (kw).
FC: Fuel consumption (L.h^{-1}).
Pr: Density of the fuel (0.85 kg.L^{-1}).
L.C.V: Lower calorific value of fuel (10000 kcal/kg).
ηm: Mechanical efficiency of engine, 80%.
ηth: Thermal efficiency of the engine, (considered to be about 40% for diesel engine).

The fuel consumption (L.h^{-1}):

By refilling the fuel tank after each operation and calculating the amount of fuel consumed during the operating time for each operation, the fuel consumption rate was calculated with the equation below **(El-Sayed, *et al.*, 2019).**

$$Fc = \frac{V}{T}$$

Where: Fc: rate of fuel consumption ($L.h^{-1}$).
V: rate of consumed fuel (L).
T: time (h).

Specific energy ($kwh.kg^{-1}$):
The specific energy was calculated by dividing the total required power by the machine's productivity as follows **(Baiomy, *et al.*, 2007), (Basiouny, *et al.*, 2015).**

$$EC = \frac{EP}{P}$$

Where: EC: Specific energy ($kwh.kg^{-1}$).
EP: Power requirements consumption during the chopping operation (kW).
P: Machine productivity ($kg.h^{-1}$).

Power to accelerate the forage (kw):
To estimate the feed driving capacity (kw), which corresponds to the feed rate and circumferential speed of the cutter, the equation below is used **(Srivastava, *et al.*, 1993):**

$$Paccle = \frac{mf \times Vp2}{2000}$$

Where: Paccle: Power to accelerate the forage (kw).
mf: feed rate ($kg.s^{-1}$).
Vp: circumferential speed of cutter ($m.s^{-1}$).
The circumferential speed of the cutting disc was determined using the equation below **(Pathak & Mathur, 2010).**

$$Vp = \frac{\pi \times DN}{60}$$

Where: Vp: Circumferential velocity of cutting disc ($m.s^{-1}$).
$\boldsymbol{\pi}$: constant ratio (3.14). D: Diameter of cutting disc (m).
N: speed of cutting disc rpm.

RESULTS

Productivity ($kg.h^{-1}$):
Table (2) shows the effect of the type of knife, feeding speed, type of crop, and their interaction on machine productivity ($kg.h^{-1}$). The table showed that there was a significant difference when changing the type of knife from a knife with a smooth edge to a knife with a serrated edge, which led to an increase in productivity from(103.20 to 109.60 $kg.h^{-1}$) the results

consistent with (Mady, Abdel-Hadi, Abd-Allah, & Ali, 2015). Table (2) also showed that there was a significant difference when changing the feed speed from (5.5 - 9.5 rpm), which led to an increase in productivity of (90.20-122.60 $kg.h^{-1}$) and this is consistent with what was found by **(Younis, *et al.*, 2002)**and **(Hassan, 2019)**. It was also observed that there were significant differences when changing the type of crop from corn stalks to palm fronds. To increase productivity from (104.70 - 108.10 $kg.h^{-1}$). The reason for that may be related to the decrease in cutting time for the palm frond crop, which led to an increase in productivity.

The bilateral interaction between the type of knife and the feeding speed had a significant effect on the productivity, as the highest productivity occurred between the speed (9.5 rpm) and the knife with a smooth edge, where it was (123.80 $kg.h^{-1}$).

From the same table, we note that there are significant differences in the bilateral interaction between the type of crop and the type of knife, as it was found that the highest productivity occurred in the type of palm frond crop and the type of knife with a smooth edge, where it was (108.20 $kg.h^{-1}$).

The interaction between crop type and feeding speed was insignificant, with the highest productivity recorded (124.10 $kg.h^{-1}$) in the palm fronds crop type and feeding speed (9.5 rpm). The interaction between the knife type, Feed speed, and Crop type has a non-significant effect on machine productivity. The smooth-edged knife with the speed (5.5 rpm) with palm fronds achieved the lowest average productivity (87.90 $kg.h^{-1}$), while the smooth-edged knife with the speed (9.5 rpm) with palm leaves recorded the highest average productivity, as it was (128.50 $kg.h^{-1}$).

Table (2): The effect of knife type, feeding speed, and crop type on productivity (kg/h).

productivity($kg.h^{-1}$)					
C * S		**(N) Knife type**		**Feed speed (S)**	**Crop type (C)**
		Smooth	**Serrated**		
92.00		**87.90**	**96.20**	**(5.5rpm) Slow**	**Palm**
124.10		**128.50**	**119.70**	**(9.5rpm) Fast**	
88.30		**119.20**	**99.20**	**(5.5rpm) Slow**	**Corn**
121.20		**119.20**	**123.20**	**(9.5rpm) Fast**	
N.S	**LSD C*S**	**N.S**		**LSD C*S*N**	
C * N					
Average crop		**Smooth**	**Serrated**	**Crop type**	
108.10		**108.20**	**108.00**	**Palm**	
104.70		**98.30**	**111.20**	**Corn**	
4.49	**LSD C**	**3.57**		**LSD C*N**	
S * N					
Average feeding speed		**Smooth**	**Serrated**	**Feed speed**	
90.20		**82.60**	**97.70**	**(5.5rpm) slow**	
122.60		**123.80**	**121.40**	**(9.5rpm) Fast**	
4.04	**LSD S**	**4.13**		**LSD S*N**	
N					

	Smooth	Serrated	Knife type
	103.20	109.60	Average type of knife
	2.44		LSD N

Total power Consumption (KW):

Table (3) shows the effect of knife type, feeding speed, crop type, and their interaction on the total power consumption (kw). It was noted from the table that there was a significant difference when changing the type of knife from a knife with a smooth cutting edge to a knife with a serrated cutting edge, which led to a decrease in the required power. The total power is between (8.10 - 7.00 kw), and this is consistent with the findings **of (EL-Khateeb & El-Keway, 2012)**.From the same table, it was noted that there was a significant difference when changing the feed speed from (5.5-5.9 rpm), which led to an increase in the total required power. From (7.20-7.90 kw). The results consistent with **(Abo-Habaga, *et al.*, 2019), (Radwan, *et al.*, 2016),** it was also observed that there were significant differences when the type of crop changed from corn stalks to palm fronds led to an increase in the total required power from (7.00 to 8.10 kw).The reason for this may be due to the difference in the mechanical properties of the tissues of each crop, as the power required to cut wood depends on its special mechanical properties and the design of the cutting weapon, and this is consistent with **(Kminiak & Kubs, 2016)**.

The bilateral interaction between knife type and feed speed had no significant effect on the total required power, as the highest total required power occurred between the speed (9.5 rpm) and the knife with a smooth edge, where the total required power was (8.60 kw).

From the same table, we note that there are no significant differences for the binary interaction between the type of crop and the type of knife, as it was found that the highest total required power occurred in the type of palm fronds crop and the type of knife with a smooth edge, where it was (8.60 kw).

The interaction between crop type and feeding speed was significant, with the highest total required power recorded (8.20kw) for the palm fronds crop type and feeding speed (5.5 rpm).

The interaction between the knife type, Feed speed, and Crop type has a significant effect on total power consumption. The knife with a serrated edge and the speed (5.5rpm) with corn stalks achieved the lowest total required power, which was (5.20 kw), while the smooth knife with the speed (9.5rpm) with palm leaves recorded the highest total required power, which was (9.30 kw).

Table (3): The effect of knife type, feeding speed, and crop type on required total power (KW).

Required total power (KW)				
C * S	(N) Knife type		Feed speed (S)	Crop type (C)
	Smooth	Serrated		
8.20	7.90	8.40	(5.5rpm) Slow	Palm
8.10	9.30	6.80	(9.5rpm) Fast	
6.30	7.80	5.20	(5.5rpm) Slow	Corn
7.70	7.80	7.60	(9.5rpm) Fast	
0.39 LSD_{C*S}	0.56		LSD_{C*S*N}	
C * N				
Average crop	Smooth	Serrated	Crop type	
8.10	8.60	7.60	Palm	
7.00	7.60	6.40	Corn	
0.21 LSD_{C}	N.S		LSD_{C*N}	
S * N				
Average feeding speed	Smooth	Serrated	Feed speed	
7.20	7.60	6.80	(5.5rpm) Slow	
7.90	8.60	7.20	(9.5rpm) Fast	
0.39 LSD_{S}	N.S		LSD_{S*N}	
N				
	Smooth	Serrated	Knife type	
	8.10	7.00	Average type of knife	
	0.34		LSD_{N}	

Specific energy (kwh.kg^{-1}):

Table (4) shows the effect of the type of knife, feeding speed, type of crop, and their interaction on specific energy (kwh.kg^{-1}). The table showed that there was a significant difference when changing the type of knife from a knife with a smooth cutting edge to a serrated one, which led to a decrease in the specific energy from (0.0807- 0.0647 kwh.kg^{-1}). The results consistent with **(Sayed-Ahmed, *et al*., 2009)**.The results of the table below also showed a significant difference when changing the feed speed from (5.5 - 9.5 rpm). led to a decrease in the specific energy from (0.0810 to 0.0644 kwh.kg^{-1}) because, as the feed speed increased the time taken for feeding decreases, hence the power consumption decreases at higher feed roller speeds at constant feed rate, and this agrees with **(Hassan, 2019)**. It was also observed that there were significant differences when changing the crop type of palm fronds to the stalks of the corn crop, it led to a decrease in the specific energy of (0.0767 - 0.0687 kwh.kg^{-1}).The reason for this is due to the high moisture content of the corn stalks, and the results consistent with **(Werby & Mousa, 2017).**

The bilateral interaction between the type of knife and the feeding speed had a significant effect on the specific energy characteristic, as the highest specific energy occurred between the speed (5.5 rpm) and the knife with a smooth edge, where it was (0.0922 $kwh.kg^{-1}$). From the same table, we note that there are significant differences in the bilateral interaction between the type of crop and the type of knife, as it was found that the highest specific energy occurred in the type of palm fronds crop and the type of knife with a smooth edge, where it was (0.0812 $kwh.kg^{-1}$).

The interaction between crop type and feeding speed was significant, as the highest specific energy obtained (0.0887 $kwh.kg^{-1}$) was recorded in the palm fronds crop type and feeding speed (5.5 rpm).

The interaction between the knife type, Feed speed, and Crop type has a significant effect. The smooth edge knife with and speed (5.5 rpm) with palm fronds achieved the highest specific energy (0.0900 $kwh.kg^{-1}$), while the knife with a serrated edge and speed (5.5 rpm) with corn stalks achieved the highest specific energy (0.0900 $kwh.kg^{-1}$), The lowest specific energy was (0.0523 $kwh.kg^{-1}$).

Table (4): The effect of knife type, feeding speed, crop type and their interaction on specific energy ($kwh.kg^{-1}$).

Specific energy ($kwh.kg^{-1}$)				
C * S	**(N) Knife type**		**Feed speed (S)**	**Crop type (C)**
	Smooth	**Serrated**		
0.0887	0.0900	0.0873	(5.5rpm) Slow	Palm
0.0647	0.0723	0.0570	(9.5rpm) Fast	
0.0733	0.0663	0.0523	(5.5rpm) Slow	Corn
0.0642	0.0663	0.0620	(9.5rpm) Fast	
0.0062 LSD $_{C*S}$	0.0098		LSD $_{C*S*N}$	
C * N				
Average crop	**Smooth**	**Serrated**	**Crop type**	
0.0767	0.0812	0.0722	Palm	
0.0687	0.0803	0.0572	Corn	
0.0046 LSD $_{C}$	0.0064		LSD $_{C*N}$	
S * N				
Average feeding speed	**Smooth**	**Serrated**	**Feed speed**	
0.0810	0.0922	0.0698	(5.5rpm) Slow	
0.0644	0.0693	0.0595	(9.5rpm) Fast	
0.0062 LSD $_{S}$	0.0076		LSD $_{S*N}$	
N				
	Smooth	**Serrated**	**Knife type**	
	0.0807	0.0647	Average type of knife	
	0.0062		LSD $_{N}$	

Power to accelerate the forage(kw):

Table (5) shows the effect of the type of knife, feeding speed, type of crop, and their interaction on power to accelerate the forage (kw). It was noted from the table that there is a significant difference when changing the type of knife from a knife with a smooth cutting edge to a serrated one, which led to an increase in the power to accelerate the forage from (0.049-0.054 kw) The reason for this is due to the direct relationship with productivity, whereby increasing productivity increases the force of accelerate the forages. From the same table, it was noted that there is a significant difference when changing the feed speed from (5.5-5.9 rpm), which led to an increase in the power required to accelerate the forages from (0.043-0.059 kw). The results consistent with **(Rawdhan, *et al.*, 2024)**.It was also observed that there were significant differences when changing the type of crop from corn stalks to palm fronds, which led to an increase in the power required to accelerate forages from (0.050-0.053 kw), The reason for this may be due to the low moisture content of palm fronds.

The bilateral interaction between knife type and feed speed was significant on the power required to accelerate the forages, as the highest power to push the forages occurred between the speed (9.5rpm) and the knife with a smooth edge, which was (0.060kw).
From the same table, we note that there are no significant differences for the bilateral interaction between the type of crop and the type of knife, as it was found that the highest power required to accelerate forages occurred in the type of corn stalk and the type of knife with a smooth edge, and it was (0.055 kw).

The interaction between crop type and feeding speed was insignificant, as the highest power required to accelerate forages was (0.060 kw) in the palm frond crop type and feeding speed (9.5 rpm).

The interaction between the knife type, Feed speed, and Crop type has a non-significant effect on power required to accelerate forages. The smooth edge knife with and speed (9.5 rpm) with palm leaves achieved the highest ability to accelerate forages, which was (0.063 kw), while the knife with a smooth edge and speed (5.5 rpm) with palm leaves recorded the lowest. Power required to accelerate forages was (0.044kw).

Table (5): The effect of knife type, feeding speed, crop type, and the interaction between them on the power required to accelerate forages (kw).

<table>
<tr><th colspan="6">Power to accelerate the forage (kw)</th></tr>
<tr><th colspan="2" rowspan="2">C * S</th><th colspan="2">(N) Knife type</th><th rowspan="2">Feed speed (S)</th><th rowspan="2">Crop type (C)</th></tr>
<tr><th>Smooth</th><th>Serrated</th></tr>
<tr><td colspan="2">0.045</td><td>0.044</td><td>0.047</td><td>(5.5rpm) Slow</td><td rowspan="2">Palm</td></tr>
<tr><td colspan="2">0.060</td><td>0.063</td><td>0.058</td><td>(9.5rpm) Fast</td></tr>
<tr><td colspan="2">0.042</td><td>0.057</td><td>0.050</td><td>(5.5rpm) Slow</td><td rowspan="2">Corn</td></tr>
<tr><td colspan="2">0.058</td><td>0.057</td><td>0.060</td><td>(9.5rpm) Fast</td></tr>
<tr><td>N.S</td><td>LSD C*S</td><td colspan="2">N.S</td><td colspan="2">LSD C*S*N</td></tr>
<tr><th colspan="6">C * N</th></tr>
<tr><th colspan="2">Average crop</th><th>Smooth</th><th>Serrated</th><th colspan="2">Crop type</th></tr>
<tr><td colspan="2">0.053</td><td>0.053</td><td>0.053</td><td colspan="2">Palm</td></tr>
<tr><td colspan="2">0.050</td><td>0.045</td><td>0.055</td><td colspan="2">Corn</td></tr>
</table>

0.002	LSD_{C}	N.S		LSD_{C*N}
S * N				
Average feeding speed		Smooth	Serrated	Feed speed
0.043		0.039	0.048	(5.5rpm) Slow
0.059		0.060	0.059	(9.5rpm) Fast
0.005	LSD_{S}	0.005		LSD_{S*N}
N				
		Smooth	Serrated	Knife type
		0.049	0.054	Average type of knife
		0.004		LSD_{N}

Conclusions

From the results obtained the study, the following conclusions were achieved:

- The knife with a serrated edge knife achieved the highest productivity, the lowest total power required, and the lowest specific energy at a feed speed (5.5 rpm).
- The crop (corn stalks) gave the lowest total power required, the lowest power required to push forages, and the lowest specific energy at feeding speed (5.5 rpm).

Recommendations:

To achieve the highest productivity when using a feed cutting machine, it is recommended to use a serrated edge knife at a rotational speed of the cutting cylinder (1450 rpm) and a feed speed (5.5 rpm) to provide an outstanding feed that fill the shortage in the market of traditional feeds.

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