Performance Evaluation of a Sugarcane Peeling Machine

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Abstract

Machinery removal of sugarcane leaves reduces harvest costs, time, and effort. Therefore, designing and manufacturing a sugarcane peeling machine using locally available raw materials is of imminent importance. Three sets of drums were designed: the first is used for in-take and cleaning of stalks, the second is used to help scroll and clean stalks, and the third is used for further cleaning and discharge of stalks. The manufacture of the machine relied on metal and rubber, and used a diesel engine with a capacity of 24.5 hp and a speed of 2150 rpm. The idea was based on the principle of friction and pressure. Experimental tests were applied to study the efficiency of the machine and its effect on the crop during peeling, during which several parameters were applied. Tests were applied to (G.T.54/C9, also known as C9) sugarcane variety, which is the only commercially cultivated variety in Egypt. Parameters focused on stalk damage rate as well as on discharge distance. They were applied to both intact straight stalks, which were properly cultivated and served, and logging stalks, on three weaning periods: 10 days, 20 days, and 30 days; and at three velocities: 500 rpm, 600 rpm, and 700 rpm. The performance and efficiency of the machine through the parameters of speed (rpm), discharge distance (m), stalk damage rate (%), quantity of production (t/h), and consumption of fuel (l/h), with the age of weaning being set to 30 days, were measured. Parameters applied at a 700-rpm velocity, showed the best results in the case of straight stalks, on various parameters including discharge distance (1.55 m), stalk damage rate (0.5%), quantity of production (5.040 t/h), and consumption of fuel (1.55 l/h) at a 30-day weaning period. Parameters applied at a 600-rpm velocity, showed the best results in the case of logging stalks, on various parameters including discharge distance (0.35 m), stalk damage rate

(25.34%), quantity of production (3.960 t/h), and consumption of fuel (1.45 l/h)) at a 30-day weaning period.

***Keywords*: Sugarcane, Peeling machine, Leaf remover, Sugarcane leaf stripper, Sugarcane mechanization.**

Introduction

Sugarcane is a globally important crop, since it provides most of the sugar consumed worldwide. This plant is a crucial source of food, forage, and bioenergy, among other products, and represents an important component of the economy of 130 countries and territories located in the tropics and subtropics all over the world [(1)]. The juice from sugarcane stalks is highly prized and approximately 70% of the global sugar production is derived from sugarcane [(2)]. Some physical and mechanical properties of sugarcane mainly include stalk dimensions, mass, number of nodes, stalk curvature, hardness and coefficient of friction and their relation to mechanization. It was found that the average length and diameter of the sugarcane stalk for the Egyptian variety (G.T.54/C9) was 178 cm and 2.3 cm respectively. The average stalk mass was 0.794 kg. The average stalk and average coefficient of friction were 8.8 degree for wood, 7.6 for rubber and 8.9 for steel. Sugar industry in Egypt and many countries around the world depends on the two basic crops: sugarcane and sugar beet [(3)]. Cultivated area of sugarcane in Egypt reached up to 332.000 feddans, with an average production of 48.9 tons per feddan, and the total planted area of sugar beet in Egypt reached up to 423.000 feddans, with an average production of 21.5 tons per feddan. Egypt produces about 2.29 million tons of sugar from cane and beet sugar crops [(4)]. Sugarcane trash (leaves + tops) removal takes 65% time of manual harvesting and which takes 45 to 48% of total cultivation cost [(5)]. Sugarcane harvesting includes stalk cutting and stripping of dry leaves and tops. Leaf stripping is not only performed at time of harvesting but also during different growth stages of sugarcane to enhance sugarcane yield [(6)]. It takes 65% time of manual sugarcane harvesting [(7)]. About 10 % deductions in selling price are observed if trash (leaves and tops) is not removed properly [(8)]. Therefore, it is required to remove the dry leaves before transporting to mill.

Burning is most common practice to remove trash from standing crop stalks before harvesting [9]. Initially this practice was considered easy and cost beneficiary but studies have revealed that burning practice not only decreases the sugar content but also reduces weight, sweetness and organic material from soil [10]. Furthermore, this burning action in standing crop wastes all biomass material which can be used for animal feeding and as a source of renewable energy to mitigate natural resources and energy[5]. Sugarcane mechanical harvesting systems are classified as two methods: one of them is cut-chop-harvesting or chopper harvesting system (the system chops the cane into billets during harvesting). This system is also called sugarcane combine harvesting system. The other is whole-stalk sugarcane harvesting system (a system that delivers the whole stalk of canes). Large self-propelled whole stalk harvesters are operated only within full mechanization systems [11].

A sugarcane cleaner was developed and evaluated to operate with PTO of a tractor. The machine was fed with 4 stalks, 6 stalks, and 8 stalks at a time, using three flap roller speeds 350, 600 and 850 rpm respectively, with two sugarcane varieties. The topping efficiency increased with the increase in the flap roller speed from 6.78 to 16.46 m/s for both varieties, and decreased with the increase in the number of canes fed from 4 to 8 canes at a time for both varieties. A maximum topping efficiency of 89.18% and 93.98% was achieved for the COJ-64 and CO-1148 varieties, respectively, whereas there was a minimum mill trash of 3.62% and 2.26% for COJ-64 and CO-1148 variety, respectively [12].

There are two methods to peel sugarcane from the leaf and trash: The first method is based on compressed air, and is used in large harvesters, for example, the chopper harvester; whereas the chopper cuts the whole stalk of the cane into pieces. The second method is used to clean the cane from dry leaves by means of a centrifugal process. This method is adopted in small machines. Moreover, a study has been conducted on the effect of the orientations of cleaning system on the de-trashing efficiency and found that high de-trashing efficiency was achieved when the brushes were working opposite to the direction of the leaves formation [13].

The use of leaf-removal machinery in the post-harvest production of sugarcane reduces harvest production time and contamination. The number of leaves and leaf sheaths affect the speed of harvest production. Moreover, leaves and leaf sheaths increase the waste material in production. They also contaminate the sugar and the sugar production system with clay, sand, and mud from the fields. Traditional methods for sugarcane harvest without removing leaf took 37 h/rai (rai = 1600 m^2) to complete, but sugarcane leaf removing could reduce the sugarcane harvest process to 11.4 h/rai (14).

Objectives of manufacturing the sugarcane-peeling machine:

1. Reducing agricultural service costs.
2. Addressing the scarcity of labor during harvest season.
3. Providing necessary time and effort to complete the harvesting process.
4. To help complete the harvesting process on due time for supply.
5. Manufacturing a low-cost machine suitable for small-scale farmers.
6. Addressing the problem of fragmented cultivated land holdings.

Materials and methods

The machine consists of a frame, a diesel motor, and three sets of drums. The machine has a 24.5 horsepower diesel motor, with a speed of 2150 rpm. The motor is responsible for supplying the equipment with movement. The frame is mainly provided to assemble the parts of the machine and reduce vibration and noise rate resulting from the movement of drums. This part consists of an external box which mainly assembles other parts. Drums are divided into several sets, each set consisting of a pair of drums:

- The first drum set is responsible for stalk in-take and cleaning
- The second drum set is responsible for scrolling and cleaning
- The third set is responsible for cleaning and discharge

The machine prototype has a mass of 250 kg (not including the diesel motor) and consists of the following parts:

A) In-take and cleaning unit:

A pair of horizontally paralleled drums (Figure 1). Each drum contains six cleaning combs, which pull the stalks, perform a preliminary cleaning, and pass them to the second set, and in to the next one, to continue the cleaning process.

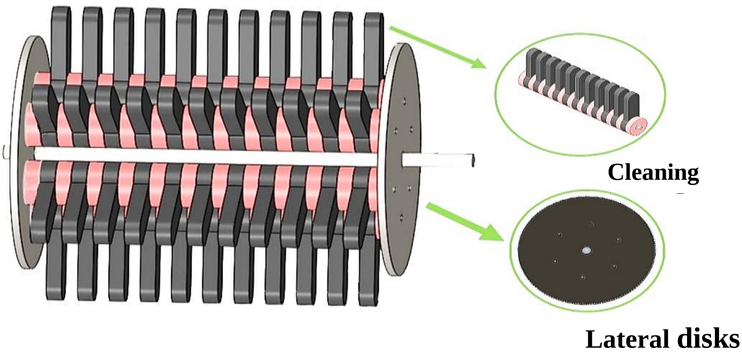

Figure (1): In-take and cleaning unit

The in-take unit consists of the following parts as shown in figure 1:

1. **Cleaning comb:**

The cleaning comb is a set of fingers assembled respectively.
Each set of the in-take and cleaning unit consists of six combs. Each comb consists of a finger assembly tube of 46 cm in length and an outer diameter of 18 mm, which is fixed to the cylinders by a steel bar.
The comb has 20 rubber fingers, separated by 21 rubber separators. Each comb is bordered by a pair of steel supports, which stabilize the comb and keep it perpendicular to the axis in the upright position and support it during operation, as shown in figure 1.

2. **Cleaning finger:**

The cleaning comb consists of a small unit (cleaning finger) made of rubber, 16 cm long, 5 cm wide and 1 cm thick. These fingers pull the stalks by means of friction and perform an initial cleaning, as shown in figure 2.

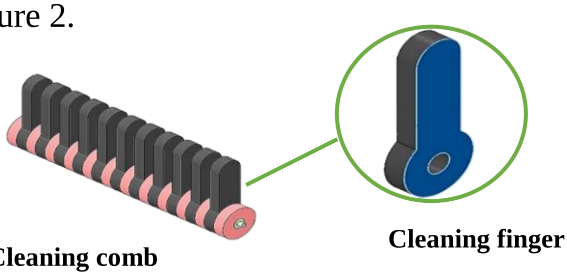

Figure (2): Cleaning Comb.

3. **Lateral disks:**

The lateral disk assembles the parts of the drum. The in-take and cleaning unit has a pair of steel discs, each with a diameter of 37 cm and a thickness of 10 cm, and contains six holes of 16 mm diameter, as shown in figure 1.

4. **Rotation axis:**

The parts of the drum are assembled by a rotation axis. It is the part responsible for the assembly, installation and rotation of the drum. It rotates on two chassis-mounted loading chairs and a transmission gear.

B) Scroll and cleaning unit:

In terms of components, it is just like the in-take and cleaning unit. It cleans the stalks almost completely, passing them to the third set (discharge unit).

C) Discharge unit:

The discharge unit, shown in figure 3, finishes the cleaning process then expels the cleaned stalks out of the machine. It consists of rubber plates of 45 cm long, 16 cm high and 2 cm thick.

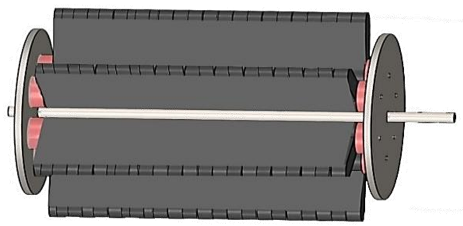

Figure (3): Cleaning and discharge unit.

Sequence of machine performance:

1. Direction of stalk in-take.
2. Direction of drum rotation.
3. In-take and cleaning drum set.
4. Scroll and cleaning drum set.
5. Cleaning and discharge drum set.

A worker starts by placing the stalks from the front, where the first set of drums begins to spin in, pull and clean the stalks. At this stage, the cleaning process is done by lateral friction (vertically) through cleaning combs made of rubber and installed as the main cleaning unit on the first set. Then these combs pass the stalks to the second drum set which acts like the previous one. It confirms the cleaning process in the same way as the first set, passing the stalks to the third and final set of the machine. The third set of drums completes the process of cleaning the stalks by means of a top-to-bottom friction, to remove the residue of leaves. This set also expels the stalks out of the machine. The sequence of cleaning sugarcane stalks inside the machine is shown in figure 4.

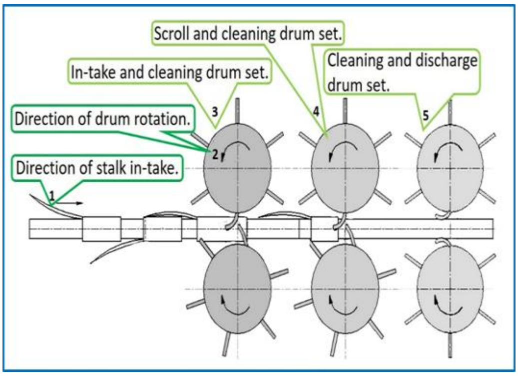

Figure (4): Sequence of machine performance

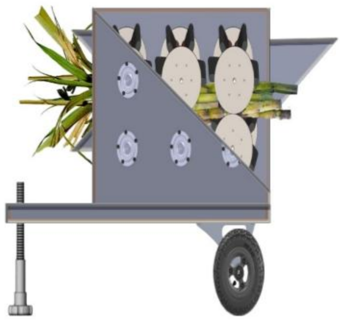

Figure (5): Machine assembled

Evaluation Factors:

Fuel Consumption Rate:

By determining the volume of fuel consumed during a given time, we can calculate the rate of fuel consumption (R. F. C.), using the following equation:

$$\text{RFC. (l/h)} = \frac{\text{Consumed fuel (l)}}{\text{Time of operation (h)}} \quad \text{.... (1)}$$

$$\text{Fuel consumption (l/fed)} = \frac{\text{Fuel consumption (l/h)}}{\text{Actual field capacity (fed/h)}} \quad \text{... (2)}$$

Results and discussion

Experiments were carried out at farmers' field and applied to (G.T.54/C9) sugarcane variety in Assiut governorate, Egypt, in 2018.

Parameters focused on the effects of weaning period and drum speed. Weaning period parameters included three weaning period categories: 10 days, 20 days, and 30 days. The 30-day weaning period (number of days from last irrigation to harvest) is the ideal one and it complies with the specifications of sugarcane supply to sugar mills.

Machine speed was tested at three velocities: 500 rpm, 600 rpm, and 700 rpm, on both averages of stalk damage rate (percentage of stalks that break during leaf-removal, out of the total cleaned stalks) and discharge distance (the distance to which a stalk is ejected by the machine after leaf-removal). Parameters were applied to both intact straight stalks, which were tied up and served well, and logging stalks (sprawled or leaning down stalks) as a result of negligence in tying up and being exposed to adverse weather conditions.

1. Effect of drum speed on the average of stalk damage rate:

Table (1): Effect of weaning period and machine velocities on average damage rate (%), in the case of straight stalks.

Weaning period / Drum speed (rpm)	10 days weaning	20 days weaning	30 days weaning	Average
500	20.14 c	3.23 f	0.30 g	7.89 C
600	25.36 b	7.11 e	0.35 g	10.94 B
700	30.41 a	10.15 d	0.50 g	13.69 A
Average	25.30 A	6.83 B	0.38 C	

(1) Means followed by the same small letter(s) do not significantly differ at 0.05 level of probability.
(2) Means followed by the same capital letter, within the same column, do not significantly differ at 0.05 level of probability.

(3) Means followed by the same capital letter (in parentheses), within the same row do not significantly differ at 0.05 level of probability.

Table (1) shows the effect of weaning period and machine velocities on average damage rate (%), in the case of straight stalks.

- The first parameter, which was applied to a 10-day weaning period and at a 500-rpm velocity, gave a 20.14% damage rate
- The second parameter, which was applied to a 10-day weaning period and at a 600-rpm velocity, gave a 25.36% damage rate
- The third parameter, which was applied to a 10-day weaning period and at a 700-rpm velocity, gave a 30.41% damage rate
- The fourth parameter, which was applied to a 20-day weaning period and at a 500-rpm velocity, gave a 3.23% damage rate
- The fifth parameter, which was applied to a 20-day weaning period and at a 600-rpm velocity, gave a 7.11% damage rate
- The sixth parameter, which was applied to a 20-day weaning period and at a 700-rpm velocity, gave a 10.15% damage rate
- The seventh parameter, which was applied to a 30-day weaning period and at a 500-rpm velocity, gave the best result (0.30% damage rate)
- The eighth parameter, which was applied to a 30-day weaning period and at a 600-rpm velocity, gave a 0.35% damage rate
- The ninth parameter, which was applied to a 30-day weaning period and at a 700-rpm velocity, gave a 0.50% damage rate.

Table (2): Effect of weaning period and machine velocities on average damage rate (%), in the case of logging stalks.

Weaning period / Drum speed (rpm)	10 days weaning	20 days weaning	30 days weaning	Average
500	45.12 c	35.36 e	15.11 g	31.86 C
600	55.25 b	45.41 c	25.34 f	42.00 B
700	75.19 a	55.22 b	39.47 d	56.62 A
Average	58.52 A	45.32 B	26.64 C	

Table (2) shows the effect of weaning period and machine velocities on average damage rate (%), in the case of logging stalks.

- The first parameter, which was applied to a 10-day weaning period and at a 500-rpm velocity, gave a 45.12% damage rate
- The second parameter, which was applied to a 10-day weaning period and at a 600-rpm velocity, gave a 55.25% damage rate
- The third parameter, which was applied to a 10-day weaning period and at a 700-rpm velocity, gave a 75.19% damage rate
- The fourth parameter, which was applied to a 20-day weaning period and at a 500-rpm velocity, gave a 35.36% damage rate
- The fifth parameter, which was applied to a 20-day weaning period and at a 600-rpm velocity, gave a 45.41% damage rate
- The sixth parameter, which was applied to a 20-day weaning period and at a 700-rpm velocity, gave a 55.22% damage rate
- The seventh parameter, which was applied to a 30-day weaning period and at a 500-rpm velocity, gave the best result (15.11% damage rate)
- The eighth parameter, which was applied to a 30-day weaning period and at a 600-rpm velocity, gave a 25.34% damage rate
- The ninth parameter, which was applied to a 30-day weaning period and at a 700-rpm velocity, gave a 39.47% damage rate.

2. Effect of drum speed on average of discharge distance:

Table (3): Effect of weaning period and machine velocities on average discharge distance (m), in the case of straight stalks

Weaning period / Drum speed$_{(rpm)}$	10 days weaning	20 days weaning	30 days weaning	Average
500	**0.550 h**	**0.650 g**	**0.750 f**	**0.650 C**
600	**0.750 f**	**0.850 e**	**0.950 d**	**0.850 B**
700	**1.250 c**	**1.350 b**	**1.550 a**	**1.383 A**
Average	**0.850 C**	**0.950 B**	**1.083 A**	

Table (3) shows the effect of weaning period and machine velocities on average discharge distance (m), in the case of straight stalks.

- The first parameter, which was applied to a 10-day weaning period and at a 500-rpm velocity, gave a 0.550 m discharge distance
- The second parameter, which was applied to a 10-day weaning period and at a 600-rpm velocity, gave a 0.750 m discharge distance
- The third parameter, which was applied to a 10-day weaning period and at a 700-rpm velocity, gave a 1.250 m discharge distance
- The fourth parameter, which was applied to a 20-day weaning period and at a 500-rpm velocity, gave a 0.650 m discharge distance
- The fifth parameter, which was applied to a 20-day weaning period and at a 600-rpm velocity, gave a 0.850 m discharge distance
- The sixth parameter, which was applied to a 20-day weaning period and at a 700-rpm velocity, gave a 1.350 m discharge distance
- The seventh parameter, which was applied to a 30-day weaning period and at a 500-rpm velocity, gave a 0.750 m discharge distance
- The eighth parameter, which was applied to a 30-day weaning period and at a 600-rpm velocity, gave a 0.950 m discharge distance
- The ninth parameter, which was applied to a 30-day weaning period

and at a 700-rpm velocity, gave the best result (1.550 m discharge distance)

Table (4): Effect of weaning period and machine velocities on average discharge distance (m), in the case of logging stalks

Weaning period / Drum speed (rpm)	10 days weaning	20 days weaning	30 days weaning	Average
500	**0.00 g**	**0.15 e**	**0.25 c**	**0.133 C**
600	**0.05 g**	**0.20 d**	**0.35 b**	**0.200 B**
700	**0.10 f**	**0.25 c**	**0.55 a**	**0.300 A**
Average	**0.050 C**	**0.200 B**	**0.383 A**	

Table (4) shows the effect of weaning period and machine velocities on average discharge distance (m), in the case of logging stalks.

- The first parameter, which was applied to a 10-day weaning period and at a 500-rpm velocity, gave a 0.00 m discharge distance
- The second parameter, which was applied to a 10-day weaning period and at a 600-rpm velocity, gave a 0.05 m discharge distance
- The third parameter, which was applied to a 10-day weaning period and at a 700-rpm velocity, gave a 0.10 m discharge distance
- The fourth parameter, which was applied to a 20-day weaning period and at a 500-rpm velocity, gave a 0.15 m discharge distance
- The fifth parameter, which was applied to a 20-day weaning period and at a 600-rpm velocity, gave a 0.20 m discharge distance
- The sixth parameter, which was applied to a 20-day weaning period and at a 700-rpm velocity, gave a 0.25 m discharge distance
- The seventh parameter, which was applied to a 30-day weaning period and at a 500-rpm velocity, gave a 0.25 m discharge distance
- The eighth parameter, which was applied to a 30-day weaning period and at a 600-rpm velocity, gave a 0.35 m discharge distance
- The ninth parameter, which was applied to a 30-day weaning period and at a 700-rpm velocity, gave the best result (0.55 m discharge distance)

Cleaning rate of the machine:

Experiments were conducted on 300 straight sugarcane stalks. Average of results was as follows:

Remaining trash	Number of stalks	Percentage
A part of the leaf + the sheath = 50%	15	5%
Only the sheath = 75%	39	13%
Wholly clean = 100%	246	82%

Experiments were conducted on 300 logging sugarcane stalks. Average of results was as follows:

Remaining trash	Number of stalks	Percentage
A part of the leaf + the sheath = 50%	21	7%
Only the sheath = 75%	45	15%
Wholly clean = 100%	243	78%

Performance evaluation tests were applied to the effect of drum speed on various parameters (stalk damage rate (%) - discharge distance (m) - quantity of production (ton/hour) - consumption of fuel (l/h)), at a 30-day weaning period. Parameters were applied to both straight and logging stalks. Results came as follows:

- Parameters applied at a 700-rpm velocity, showed the best results in the case of straight stalks, according to table (5), on various parameters (discharge distance (m) - stalk damage rate (%) - quantity of production (t/h) - consumption of fuel (l/h)), at a 30-day weaning period.

Table (5): The effect of drum speed on various parameters (discharge distance (m) - stalk damage rate (%) - quantity of production (t/h) - consumption of fuel (l/h)), at a 30-day weaning period, in straight stalks.

Drum speed$_{(rpm)}$	Discharge distance$_{(m)}$	Stalk damage rate$_{(\%)}$	Production quantity$_{(t/h)}$	Fuel consumption$_{(l/h)}$
500	0.75 C	0.3 0 B	4. 560 C	1.3 0 C
600	0.95 B	0.35 B	4. 800 B	1.45 B
700	1.55 A	0.5 0 A	5. 040 A	1.55 A
F-TEST	**	**	**	**

* = significant ** = highly significant, ns = not significant

Means followed by the same capital letter, within the same column, do not significantly differ at 0.05 level of probability.

- Parameters applied at a 600-rpm velocity, showed the best results in the case of logging stalks, according to table (6), on various parameters (discharge distance (m) - stalk damage rate (%) - quantity of production (t/h) - consumption of fuel (l/h)), at a 30-day weaning period.

Table (6): The effect of drum speed on various parameters (discharge distance (m) - stalk damage rate (%) - quantity of production (t/h) - consumption of fuel (l/h)), at a 30-day weaning period, in logging stalks

Drum speed$_{(rpm)}$	Discharge distance$_{(m)}$	Stalk damage rate$_{(\%)}$	Production quantity$_{(t/h)}$	Fuel consumption$_{(l/h)}$
500	0.25 C	15.11 C	3.840 C	1.3 0 C
600	0.35 B	25.34 B	3.960 B	1.45 B
700	0.55 A	39.47 A	4.080 A	1.55 A
F-TEST	**	**	**	**

Conclusion

Experiments showed that the earlier weaning time at which the machine is used to clean the stalks and remove the leaves, the higher the rate of damage would be, for both straight and logging stalks. This is due to the high humidity in the stalk and the fact that its tissues are so soft that they may not often stand the pressure and friction caused by the cleaning unit in the machine. Thus, it affects the stalk dash out of the machine, consequently decreasing the discharge distance to about 0.00 m. In contrast, the more delayed the weaning period is, the less the rate of damage would be, for both straight and logging stalks. This is due to the low humidity in the stalk and the consistency of its tissues. Thus, it affects the stalk dash out of the machine, consequently increasing the discharge distance to about 1.55 m.

Experiments also showed that the rate of damage and discharge distance in logging stalks are higher than straight ones. This is due to the impedance caused by the curved and non-straight parts of the stalk as it passes through the cleaning unit, which leads to breaking it or causing damage to it either by pressing or by cutting, thus impeding its dash out of the machine.

Parameters applied at a 700-rpm velocity, showed the best results in the case of straight stalks, on various parameters including discharge distance (1.55 m), stalk damage rate (0.5%), quantity of production (5.040 t/h), and consumption of fuel (1.55 l/h) at a 30-day weaning period.

Parameters applied at a 600-rpm velocity, showed the best results in the case of logging stalks, on various parameters including discharge distance (0.35 m), stalk damage rate (25.34%), quantity of production (3.960 t/h), and consumption of fuel (1.45 l/h)) at a 30-day weaning period.

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الملخص العربي

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تتناول هذه الدراسة تصميم وتصنيع ماكينة إزالة أوراق قصب السكر، وذلك باستخدام المواد الخام المتاحة محليًا. حيث تم تصميم ثلاثة درافيل الأول للسحب والتنظيف والثاني للمساعدة في التمرير والتنظيف والثالث للتنظيف وإخراج سيقان القصب. اعتُمد في تصنيعها على المعدن والمطاط واستُخدم محرك ديزل بقدرة 24.5 حصان وسرعة 2150 لفة على الدقيقة؛ حيث اعتمدت الفكرة على مبدأ الاحتكاك والضغط. تم إجراء بعض الاختبارات لدراسة كفاءة الماكينة وتأثيرها على المحصول أثناء التقشير؛ حيث أجريت عليها عدة معاملات استُخدم فيها صنف القصب (جيزة تايوان 9/54، والمعروف باسم C9) وهو الأكثر انتشاراً فى مصر. وتمت الاختبارات على معامل الكسر ونقطة التشوين، على كل من القصب المستقيم والمعامل زراعياً بطريقة صحيحة وكذلك القصب المصاب بالرقاد، عند أعمار فطام 10 أيام و 20 يوماً و 30 يوماً؛ وكذلك على سرعات 500 و600 و700 لفة على الدقيقة للماكينة. ثم تم قياس معدل الأداء والكفاءة للماكينة من خلال معاملات معدل السرعة (لفة/دقيقة) ونقطة التشوين (بالمتر) ونسبة الكسر(%) وكمية الإنتاج (طن/ساعة) ومعدل استهلاك الوقود (لتر/ساعة)، مع تثبيت عمر الفطام إلى 30 يوماً وهو العمر الأمثل للحصاد طبقاً لنتائج التجارب السابقة وكذلك توصيات مصانع السكر.

أثبتت الاختبارات أن أفضل النتائج كانت كالتالي :

المعاملات التي تمت عند سرعة 700 لفة على الدقيقة كانت أفضل النتائج في حالة القصب المستقيم حيث أظهرت النتائج (نقطة التشوين 1.55متر – معدل الكسر 0.5% –

كمية الإنتاج 5.040 طن/ساعة - استهلاك الوقود 1.55 لتر/ساعة) عند عمر فطام 30 يوماً.

المعاملات التي تمت عند سرعة 600 لفة على الدقيقة كانت أفضل النتائج في حالة القصب المصاب بالرقاد؛ حيث أظهرت النتائج (نقطة التشوين 0.35 متر – معدل الكسر 25.34% – كمية الإنتاج 3.960 طن/ساعة - استهلاك الوقود 1.45 لتر/ساعة) عند عمر فطام 30 يوماً.