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DEVELOPPING AND TEST PERFORMANCE OF LOCALLY FABRICATED EQUIPMENT FOR CHOPPING THE THRESHING WASTES OF SUNFLOWER CROP

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ABSTRACT

Combined equipment for seed separation and for chopping of sunflower heads was designed, locally manufactured, and evaluated. It performs many functional processes namely: scrubbing sunflower heads for seed separation, seed releasing and collecting, and chopping sunflower heads and other crop materials. The performance of that equipment has been tested versus different design and operating parameters. Performance evaluation of the fabricated equipment has been done in terms of equipment productivity seed damage seed cleaning efficiency uniformity of head chopping, and power unit required for accomplishing all processes. The results of this study showed that using the designed equipment for cutting sunflower heads can used with high performance productivity of 189.08 kg/h at 21.4% d.b moisture content and at the cutting drum tip speed of 34.01 m/s when lengths of neck with heads of 25 cm. Whereas, the higher distribution percentage was 89 for cutting width distribution range of 2.5-4 cm at length of stalks with heads 10 cm when the moisture content was 10.5% d.b at cutting drums speed of 28.78 m/s. At increasing cutting drum tip speed from 15.69 m/s to 34.01 m/s at moisture content of 21.4% d.b and length of neck with heads of 10 cm, the energy consumption increases with about 23%.

INTRODUCTION

Handling and recycling threshing residues is one of the most critical problems, which face the Egyptian farmer especially after threshing sunflower crop. Threshing residues of sunflower can be an excellent alternative feed for cattle and sheep. Recently, chopping and incorporation of threshing residues of sunflower into other forage being ensiled at the same time, such as corn, small grains, or sorghum sorghum-Sudan, can most easily ensile damaged sunflowers.

Although sunflower heads, after seed removal, are usually considered an agricultural waste, they are a promising source of low-methoxyl pectin (Wang et al., 1997).The sunflower head portions are one of the most palatable crop residues. The dry matter of the head represents approximately 44 percent of the weight of seeds produced per acres. This percent figure can be used to estimate the amount of consumable head material available on a field, based on upon seed yield. In addition sunflower stalks are lower in digestibility when compared to the sunflower head. Karaman et al. (2006) showed that sunflower stalk could be grinded to 5-10 mm length to be used in gypsum composites to improve thermal properties. Also, paper sheets could be obtained from the sunflower stalks (Caparrós et al., 2008). Drackley et al. (1985) showed that sunflower crop residue, a mixture of stalks and heads, contained 65.4% dry matter, and dry matter was 6.1% crude protein, 66.9%

neutral detergent fiber, 56.6% acid detergent fiber, 15.7% lignin, and 12.6% total ash.

Many researchers reviewed that chopping is necessary as a pre-treatment for incorporation into animal feed other forage and into the soil of residual straw from harvesting (Crane, 1985; Abdel Makscud et al., 1994, and El-Iraqi et a., 2002). On the other side, fodder preparation and other manufacturing processing operations are frequently requiring chopping (cutting) of agricultural materials. Cutting of plant components (agricultural materials) is applied nearly continuously during harvesting, in the separation and subsequent (Badr, 1997). The primary step in the operation of compost, processing is the size reduction of the crop residual *(*Arif, 1999*)*. Persson (1987) indicated when stem nodes were solid and stronger than the internodes so, there is a need to determine the forces and pressures require to crush the stems especially around the nodes. Some researchers reviewed the engineering factors affecting the chopping process. However, Koegel et al. (1985) used small prototype cutter head consisting of two rotary knives with an advantageous knife edges. Results indicated that the advantageous edge configuration with (45° or 90°) has the potential for significantly reducing the specific cutting energy of forages .However, with a less advantageous edge configuration the specific energy requirement can be as high or higher than conventional cutter heads for the same mean length of cut

Glibertson and Knight (1986) reviewed straw chopper performance criteria and listed three important aspects of chopper performance as (1) length reduction (2) straw damage (for more rapid decomposition in the soil), (3) power consumption. Kepner et al. (1992) defined the length of cut as the amount of advance of feed mechanism between the cutting successive knives. They added that, cutting takes place due to a system of forces acting on the material to cause it to fail in shear. This shear failure is almost invariably accompanied by some deformation in bending and compression, which increase the amount of the work required for cutting. A common way of applying the cutting forces is by means of two opposite shearing elements, which meet and pass each other with little or no clearance between them. Either one or both of elements may be moving on linear with uniform velocity. Arif (1999) developed and evaluated small agricultural residue-choppers. It was found that the cost of composting peach branches was 55 L.E/t. Nasr (2000) reported that the productivity of the chopper is proportional with drum speed, moisture content and feeding speed. Tarek et al. (2001) developed a sunflower straw chopper. Their results cleared that the productivity of the developed machine was 0.95 ton/h at 2000 rpm rotor speed and the cutting lengths of (1-9 cm) reached 95.23% from the total amount of cutting residue. İnce et al. (2005) determined for sunflower (*Heliantus annus* L.) stalk bending stress, modulus of elasticity, shearing stress and specific shearing energy. The results showed that the bending stress decreased as the moisture content increased. The average bending stress value varied between 37.77 and 62.09 MPa. The modulus of elasticity in bending also decreased as the moisture content and diameter of stalks increased. The average modulus of elasticity varied between 1251.28 and 2210.89 MPa. Also, the shearing stress and the specific shearing energy increased as the moisture content increased. The maximum shearing stress and specific shearing energy were 1.07 MPa and 10.08 MJ mm^{-2}, respectively. Both the shearing stress and the specific shearing energy were found to be higher in the lower region of the stalk due to structural heterogeneity.

Chopping is an important process to increase use of field wastes efficiently either as fodder, buried or fertilizes the soil. Harvesting by combine without chopping makes a serious problem for soil preparation when dealing with stalks that remain on the field. As a result, more power is required to get red of stalks and corporate in the soil. Also, the field crop residues could be used for making compost and improvement soil properties, animal feeding, energy source (direct burning, biogas generation) and in the field of industrial application. Therefore, straw chopping is necessary as a pre-treatment for incorporation into the soil or in other different uses. Where, the successful chopping reduces the length of straw avoiding long pieces of material fouling on cultivation and swing implement. It also eases the mixing process with soil and active biological breakdown of the straw through the soil or making compost.

During the last decade, many kinds of chopping machines have been introduced or manufactured In Egypt, which deal with residues. These machines have different theories of operation, technical specification, quality of product and productivity. The theory of operation for any type of chopping machines depends on shearing or impact forces in cutting and chopping process. The chopping machines using impact forces in cutting and chopping consume more power than that using shearing force. Besides it has heavy construction and high operation cost. From this point of view, the main objective of this study is to develop and test the performance of locally fabricated equipment for chopping sunflower heads directly after threshing processes. A developed cutting unit could be attached to a developed threshing unit to cut sunflower crop threshing residues. The developed cutting unit applies the theory of shearing force to reduce energy requirements and cutting cost/ ton. In addition, it gives the desired head cutting lengths for different uses especially for incorporation into other forage being ensiled at the same time.

MATERIALS AND METHODS

The aim of the present study is to develop and evaluate the performance of locally fabricated equipment for threshing, and chopping the threshing wastes of sunflower crop. Fig. (1) shows the functional process diagram of the developed equipment. Meanwhile, Fig. (2) shows the main, mechanisms that accomplished these functions.

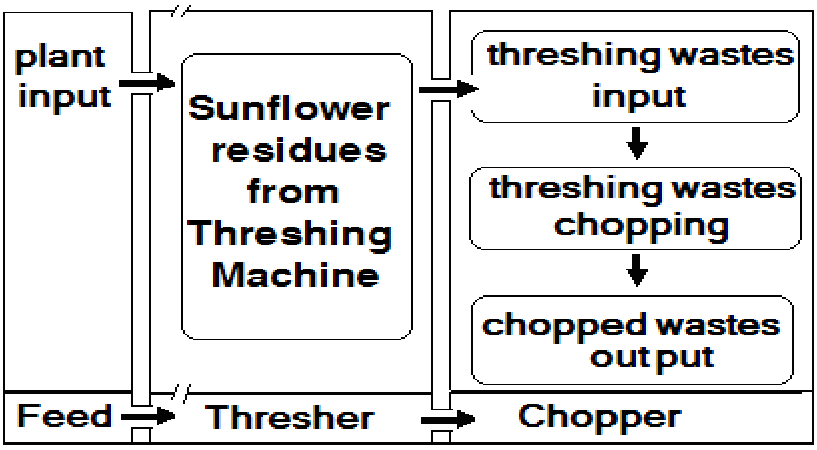

Fig. (1): The functional process diagram of the developed equipment.

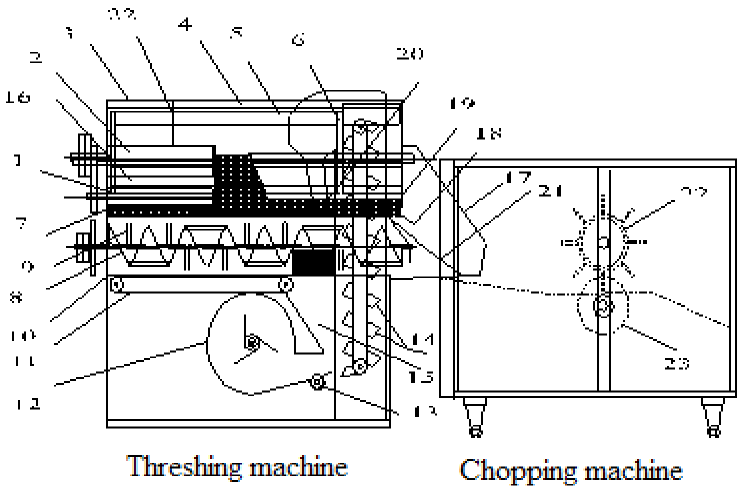

Fig. (2): The main mechanisms of the developed equipment.

The developed equipment, accomplished these functions as follows: The movable belt (1) delivers the heads contained seeds plants across the orifice to the threshing drum. As the drum rotates, the knives on the drum (2) scrub sunflower heads. Hence the seed extraction is done by a combination of impact and rubbing actions the scrubbing seed mass is displaced not only in the plane of the drum rotation, but also in its knife axial direction. The diaphragms are forced heads to transport to a central location on the drum. The mass charge performs a series of cyclic operations. Then the fingers of the separating unit (3) repeat impact and rubbing actions on the head crushed mass. Consequently, most of the seeds pass through the concave holes and fall down ward on the inclined plate. This mixture falls into the inclined plate and moves towards the front of the screw conveyer (4). The conveyer carries the seeds and delivers it to buckets unit (5). While, the heads and other threshing wastes are delivered to outlet inclined potion at the end of the drum where the heads is released. The threshing wastes (heads) discharge from the outlet inclined orifice is at a rate specified by the threshing drum speeds which are tested.

Table (1) : Technical Specifications and operating parameters of the developed Chopping machine

Item	Specifications
*Main Dimension	
- Overall length, cm	130
- Overall width, cm	70
Overall height, cm	110
Make	**Local - Egypt**
*Transmission System	
Driving pulley diameter cm	25
Driven pulley diameter cm	10
pulley subsidiary diameter cm	20
pulley of cutting drum diameter cm	10
pulley subsidiary diameter cm	30
Belt	V-belt
Prime mover	Belt
Method of feeding	Manual or Discharging outlet of threshing machine
*Knives	
- Type	11 disk Knives
- Diameter , cm	25
- thickness , cm	0.5
*Feeding drum	
Type	Spike tooth
No of fingers of row	12
No of rows of drum	4
Dimension of finger (L×W×T) cm	(9×3×1)

The operation theory of this cutting machine depends upon shearing force through two rotating disk knives and feeding drum, where both sets of knives participate in cutting process. The first cutting rotor knives (high speed rotor) is responsible for cutting operation and the other cutting rotor (low speed cutting rotor) is used as a counter-shear to provide the resistance against the cutting force and to facilitate feeding operation as shown in Fig. (3). During rotating cutting rotors, a cutting edge of disk knives penetrates into the crop residue material, overcoming its strength and thereby cutting it. Throughout this process, various deformations occur in the material, depending on the form of the cutting edge and the kinematics of the cutting process.

Methodology:

The present study was conducted during agricultural seasons of 2005 and 2006 to design, manufacture and evaluate the performance of locally fabricated equipment. The experiments were carried out Nubaria Research Station, Alexandria Governorate using, sunflower variety Geza1. The main physical and mechanical properties of the investigated sunflower crop are listed in Table (1) and methods for determination these properties are investigated in another work (Abdel-Mageed et al., 2008). It should be denoted that the listed data represented a number of 100 crops which were randomly chosen from different field zones.

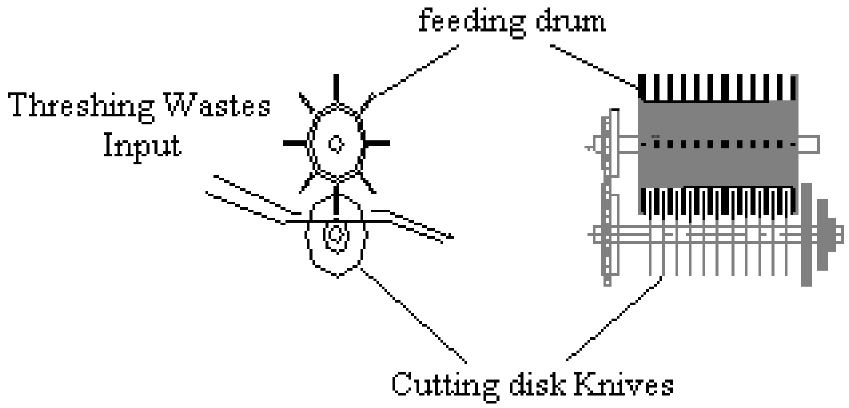

Fig. (3): Cutting Unit. (Chopping machine)

Table (2): Some physical properties of sunflower.

Characteristics	Average
Dimensions: a) Sunflower head:	
- Diameter, mm	174 ± 22.5
- Smaller thickness, mm	29.6± 6.3
- Bigger thickness, mm	67.8± 3.5
Dimensions : b) Sunflower seed:	
- Length, mm	11.5 ± 0.5
- Width, mm	6.6 ± 0.6
- Thickness, mm	3.7 ± 0.4
- Mass of sunflower head, g	246.9± 89.4
- Mass of sunflower seed g	0.12 ± 0.01
- Number of sunflower seed/head.	1547±69
- Volume of head, cm^3	777.8 ± 311.6
- Density of head, g/cm^3	0.323 ± 0.02
- Coefficient of friction	0.442 ± 0.02

The following parameters and treatments were varied during carried out the performance tests: three levels of moisture contents, three levels of feed stalk length and four levels of feeding belt speed. Each experimental test was repeated three times. Depending on the threshing, and chopping drum speeds, and the corresponding fed rate each test had its own time duration. For each performance test, the data for determining the uniformity of head chopping, the equipment productivity as a function of equipment outlet capacity of chopped heads, machinery cost unit and power unit required for chopped heads and stalks were determined.

The required power (RP) for operating the developed machine was determined using a slip ring torque transducer manufactured by El-Gwadi (2005). The specific consumed energy (CE) or that refereed as power unit (Pu) could be calculated as follows:

$$CE=Pu = \frac{RP}{Py} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where:

CE=Pu = Specific consumed energy {Energy requirement }(kW.h/ton)

Py = Machine productivity {inlet crop mass per unit time} (ton/h)

RESULTS AND DISCUSSION

Table (3): shows effect of moisture content, cutting drum speed, feeding drum speed and length of stalks with heads on the cutting width distribution percentage for cutting sunflower straw. Three cutting width distribution ranges were chosen (<2.5, 2.5-4 and >4 cm). The higher distribution percentage was 89 for cutting width distribution range of 2.5-4 cm at length of stalks with heads 10 cm when the moisture content was 10.5% d.b at cutting drums speed of 28.78 m/s. Theoretical cutting width 4 cm .The smallest distribution percentage was 2.7 for cutting width distribution range of >4 cm at length of stalks with heads 10 cm when the moisture content was 10.5% d.b at cutting drums speed of 34.01 m/s. Meanwhile, the higher distribution percentage was 85.1 for cutting width distribution range of 2.5-4 cm at length of stalks with heads 50 cm when the moisture content was 10.5% d.b at cutting drums speed of 34.01 m/s. Meanwhile, the smallest distribution percentage was 3.1 for cutting width distribution range of >4 cm at length of stalks with heads 50 cm when the moisture content was 10.5% d.b at cutting drums speed of 28.78 m/s.

Table (3): Effect of moisture content, cutting drum speed, feeding drum speed and length of stalks with heads on the cutting width distribution percentage for cutting sunflower straw.

Fig (4) illustrates the effect of cutting drum tip speed on machine capacity at different moisture content and levels lengths of neck with heads. It is obvious that increasing cutting drum tip speed results in increasing machine capacity. This happed at any level of levels lengths of neck with heads. Meanwhile, increasing moisture content resulted in increasing machine capacity. At length of neck with heads of 25 cm, the machine capacity was higher compared with other two length of neck with heads of 10 and 50 cm as illustrated in Fig. (4). This is due to the amount of coming sunflower residues from threshing machine were higher in this case (length of neck with heads of 25 cm). At length of neck with heads of 10 cm, the machine capacity was higher compared with length of neck with heads of 50 cm. This is due to that during threshing there was consumed time with length of neck with heads of 50 cm. At increasing cutting drum tip speed from 15.69 m/s to 34.01 m/s at moisture content of 21.4% d.b and length of neck with heads of 10 cm, the machine capacity increased with about 34%. At increasing cutting drum tip speed from 15.69 m/s to 34.01 m/s at moisture content of 16.6% d.b and length of neck with heads of 10 cm, the machine capacity increased with about 31%. At increasing cutting drum tip speed from 15.69 m/s to 34.01 m/s at moisture content of 10.5% d.b and length of neck with heads of 10 cm, the machine capacity increased with about 28%.

At increasing cutting drum tip speed from 15.69 m/s to 34.01 m/s at moisture content of 21.4% d.b and length of neck with heads of 50 cm, the machine capacity increased with about 33%. At increasing cutting drum tip speed from 15.69 m/s to 34.01 m/s at moisture content of 16.6% d.b and length of neck with heads of 50 cm, the machine capacity increased with about 38%. At increasing cutting drum tip speed from 15.69 m/s to 34.01 m/s at moisture content of 10.5% d.b and length of neck with heads of 50 cm, the machine capacity increased with about 31%.

The higher machine capacity was 189.08 kg/h at 21.4% d.b moisture content and at the cutting drum tip speed of 32.5 m/s when lengths of neck with heads of 25 cm. The smallest machine capacity was 117.95 kg/h at 10.5% d.b moisture content and at the cutting drum tip speed of 15.96 m/s when lengths of neck with heads of 50 cm.

Fig (5) shows effect of cutting drum tip speed on energy consumption at levels lengths of neck with heads and different moisture content. Increasing moisture content resulted in increasing energy consumption with increasing of cutting drum tip speed and at any level of lengths of neck with heads. At increasing cutting drum tip speed from 15.69 m/s to 34.01 m/s at moisture content of 21.4% d.b and length of neck with heads of 10 cm, the energy consumption increased with about 23%. At increasing cutting drum tip speed from 15.69 m/s to 34.01 m/s at moisture content of 16.6% d.b and length of neck with heads of 10 cm, the energy consumption increased with about 23%. At increasing cutting drum tip speed from 15.69 m/s to 34.01 m/s at moisture content of 10.5% d.b and length of neck with heads of 10 cm, the energy consumption increased with about 22%.

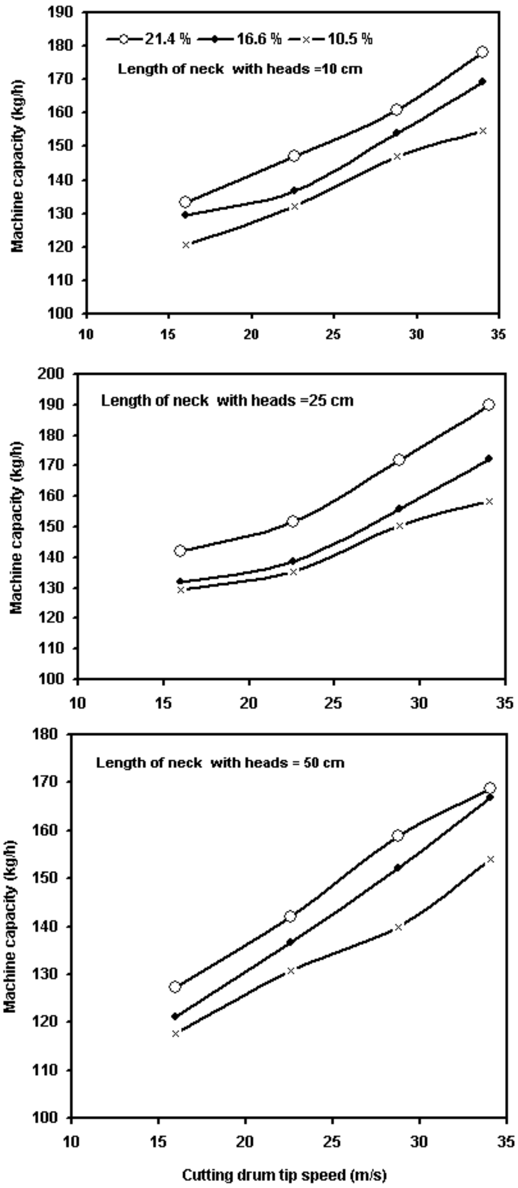

Fig (4): Effect of cutting drum tip speed on machine capacity at different moisture content and levels lengths of neck with heads

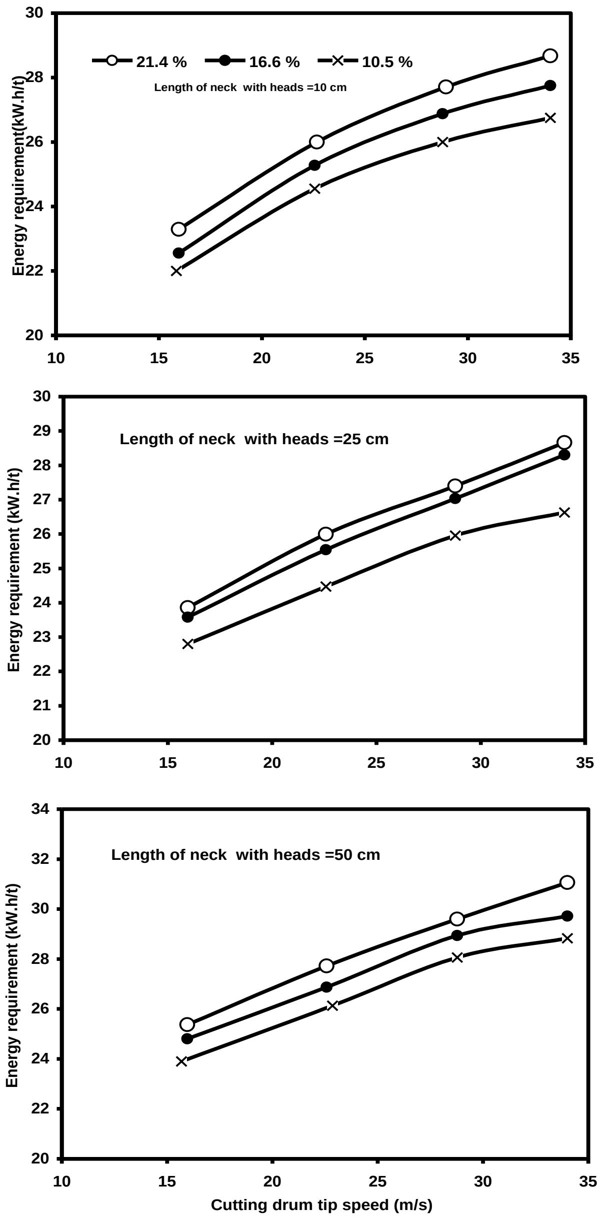

Fig (5): Effect of cutting drum tip speed on energy consumption at levels lengthsof neck with heads and different moisture content.

At increasing cutting drum tip speed from 15.69 m/s to 34.01 m/s at moisture content of 21.4% d.b, 16.6 % d.b and 10.5 % d.b and length of neck with heads of 10 cm, the energy consumption increased with about 20%,20% and 17%, respectively. Meanwhile, at increasing cutting drum tip speed from 15.69 m/s to 34.01 m/s at moisture content of 21.4% d.b, 16.6 % d.b and 10.5 % d.b and length of neck with heads of 50 cm, the energy consumption increased with about 22%,20% and 22%, respectively. At length of neck with heads of 50 cm had higher energy consumption compared with other two lengths of neck with heads and this is because the length had lower machine capacity. Meanwhile, the energy consumption at different moisture content and at lengths of neck with heads of 10 and 25 cm was close due to no more change in power requirements. As illustrated in Fig.(5)

CONCLUSIONS

The developed equipment, can be used with high performance productivity of 189.08 kg/h at 21.4% d.b moisture content and at the cutting drum tip speed of 34.5 m/s when lengths of neck with heads of 25 cm. At increasing cutting drum tip speed from 15.69 m/s to 34.01 m/s at moisture content of 16.6% d.b and length of neck with heads of 10 cm, the machine capacity increased with about 31%. The higher distribution percentage was 89 % for cutting width distribution range of 2.5-4 cm at length of stalks with heads 10 cm when the moisture content was 10.5% d.b at cutting drums speed of 28.78 m/s. At length of neck with heads of 50 cm had higher energy consumption compared with other two lengths of neck with heads and this is because the length had lower machine capacity. Meanwhile, the energy consumption at different moisture content and at lengths of neck with heads of 10 and 25 cm was close due to no more change in power requirements.

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تطوير واختبار اداء معدة محلية الصنع لتقطيع مخلفات دراس عباد الشمس

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يهدف هذا البحث إلى الاستفادة الفورية من مخلفات دراس عباد الشمس كحل ضمني لمشاكل تدوير المخلفات في مصر، وذلك من خلال تصميم وتصنيع واختبار معدة لانتزاع بذور وتقطيع أقراص وسيقان محصول عباد الشمس ؛ولكي تحل يمكن الاستفادة من مخلفات دراس عباد الشمس كمصدر طعام بديل للحيوانات محل الطرق في البيئة المصرية. وتتضمن وظائف المعدة موضوع البحث كل من عمليات فصل البذور من القرص وتجميعها من فتحة خروج البذور؛ وكذلك عمليات تحطيم وتكسير اقراص عباد الشمس لتجهيزها كغذاء للحيوانات.

ولتحقيق هذا الهدف تضمنت الدراسة تصميم وتصنيع المعدة موضوع البحث محليا حيث تكونت من وحدتين رئيسسبتين لعمليات الدراس والتقطيع - ويتم نقل القدرة من PTO للجرار إلى كل الأجزاء المتحركة بالمعدة بواسطة السيور ومجموعة من الطارات. اختبار المعدة المطورة فى عملية تقطيع رؤوس عباد الشمس تحت ظروف تشغيل مختلفة وتحديد أنسب ظروف تشغيل للآلة المصنعة . وقد أجريت تجارب اختبارات المعدة موضوع البحث فى مزرعة محطة البحوث الزراعية بالنوبارية بمحافظة الإسكندرية .و تقييم اداء الالة على ضوء انتاجية خرج المعدة وفئات ونوعية القطع وكذلك متطلبات وحدة القدرة وتكاليف التشغيل الالية. وقد أظهرت النتائج المتحصل عليها أن زيادة سرعة الدرفيل من ١٥,٩٦ الى ٣٤,٠١ أدت إلى زيادة الإنتاجية بحوالي ٣٤% عند محتوى رطوبي ٢١,٤% أساس جاف وطول الساق بالقرص ١٠ سم وأعلى إنتاجية كانت ١٨٩,٠٨ كجم /س عباد شمس مقطع عند محتوى رطوبي ٢١,٤% أساس جاف عند سرعة ٣٤,٠١ م/ث عند طول جزء ملتصق بالقرص ٢٥ سم ، والطاقة المستهلكة تزاد مع زيادة المحتولى الرطوبي وزيادة الطول الماتص باقرص لحوالي ٥٠ سم ولكن عند الأطوال ١٠ و ٢٥ سم كانت الطاقة المستهلكة متفاربة وتمكنت الآلة المطورة من تقطيع أجزاء عباد الشمس لأطوال حوالي من ٢,٥ إلى ٤ سم بنسبة ٨٩,٥%. عند سرعة تقطيع ٣٤,٠١ م/ث ومحتوى رطوبي لأجزاء عباد الشمس ١٠,٥% أساس جاف والطول الملتصق بالساق ١٠ سم . ويوصى باستخدام تصميمات معدات مجمعة لدراس وتقطيع المخلفات الدراس واختبارها لمحاصيل أخرى غير محصول عباد الشمس.