

## Manufacturing a Mechanical Unit for Grain Packing

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### ABSTRACT

This research aims to design a suitable machine for packing paddy grains mechanically to; reduce grains production costs and decrease the wasted time. An innovated new design was fabricated locally to combine various operations in one self-propelled machine from picking grains from the ground packing it into sacks by a screw elevating system, measuring the accurate needed weight tie sacks under the control of the forward and packing speeds which, synchronizing with grains layers density. The bio-engineering parameter from saving the operators from rising dusts were achieved by fixing a dust protection divider to keep dusts and weed seeds away to purify the species quality. The study included three experimental variables were as follows; four speed ratios between the winnower and screws (Sr) of (0.102, 0.123, 0.143 and 0.164) (1: 9.78, 1: 8.15, 1: 6.98 and 1: 6.11) with three levels of screw pitches (Ip) of (6, 7.5 and 9 cm) and three levels of paddy layers thickness ( $L_{th}$ ) of (5, 10 and 15 cm), while measurements included: first; the efficiencies of [picking grains ( $\eta_p$ ), volumetric capacity ( $\eta_v$ ) and machine efficiency (Me)], second; the grains damage percentage (Gd) and the machine productivity (P) third; the fuel (F) and energy consumption (Pr), fourth; the rising dusts (D) from the machine Fifth: the machine economic costs (C). The most important results included that: the maximum value of the picking grains efficiency ( $Q_p$ ) was 91.34 %, for Sr 0.164 at 9 cm of the Ip and 15 cm of the  $L_{th}$ . While, the maximum value of the conveyor screws volumetric efficiency ( $\eta_v$ ) was 93.58 % for the same factors. Besides the optimum value of the machine efficiency (Me) was 91.11 % for Sr 0.164 at 6 cm of the Ip and 5 cm of the  $L_{th}$ . Also, the highest machine productivity (P) value reaches 1.57 ton/h for Sr 0.164 at 9 cm of the Ip and 10 cm of the  $L_{th}$ . The maximum consumed energy (Pr) was 1.26 Kw.h/ton for Sr 0.102 at 9 cm of the Ip and 15 cm of the  $L_{th}$ . Nevertheless, the maximum value of the packing machine rising dusts (D) was 5.18 mg/m<sup>3</sup> for Sr 0.164 at 9 cm of the Ip and 15 cm of the  $L_{th}$ . Where, the optimum value of the machine operating cost (C) was 16.94 L.E/h for Sr of 0.102 at 6 cm of the Ip and 5 cm of the  $L_{th}$ . Studying the costs and benefits indicated that; the proposed machine can decrease the costs of packing from (25 to 17 L.E/h) as about 30 % cost reduction ratio. The internal rate of return (IRR) after considering depreciation, alternative chance costs, the amount costs of fuel and lubricants, and the rental rate calculated found 17 L.E/ h. The internal rate of return (IRR) with release year was calculated found 32%. This rate is visible compared with the current interest rate of 16% due to the capital return which was about 3 years.

**Keywords:** paddy, volumetric capacity, field efficiency and rising dusts.

### INTRODUCTION

Rice crop is considered one of the most important agricultural crop grown in Egypt, especially with increasing its cultivated area, the most harvest problems were proceeded. The over-harvesting processes are still done manually: for example packing paddy needs many labors for loading, publishing, flipping, packing, weighting and tying without using of agricultural engineering methods. So all these functions could be gathered smartly in the innovated self-propelled machine to be mechanically done, due to the lack of currently agricultural employment and the urgent needs to save time and effort. In addition to the Bio-agricultural hazards which face workers from being stressed with the impact on their spines as a result of bending for a long periods, causing cartilage slipping diseases, as well as, the effect on the respiratory system as a result of inhalation of the accumulated dusts from packing grain that cause allergies infections. In addition to, the lack of control of sacks weighing and the economic losses as a result of dragging sacks during packing operations. True packing consider very important for long-term storage. Efficient rice conveying implements are to be used to achieve energy savings. Screw conveyers (augers) are used to convey free flowing materials such as paddy rice.

The studies review was divided into two categories; the first one: the mechanical part: all of the following researchers had been evaluated the conveying materials by the screws and reported that, *Konig and Riemann (1990)* tested the influence of the inlet auger diameter on screw conveyors productivity and reported

after reaching to limit point, the auger capacity decreased with increasing the inlet screw diameter. Where, *Chang and Steele (1997)* tested two screw conveyers and showed that by increasing their rotation velocity from (413 to 690 rpm), the average power consumption doubled from 0.189 to 0.338 Kw and from 0.209 to 0.350 Kw, respectively for the inlet screw section area of 15.2 cm. Also, *Roberts (1999)* mentioned that the vortex motion results from increasing the centrifugal forces at higher rotational velocities of the screw flight diameter. As well, the vortex motion increases as a reason of the internal generated friction (friction between the conveying material granules and surface of the helical blade). The vortex motion, together with the degree of fill, control the volumetric efficiency and, hence, the volumetric throughput, however *Nicolai et al. (2004)* They reported and investigated two different screws diameter (20&25cm). The rotation speed was ranged from (250 to 1100 rpm) with inclination angles of (13, 20 and 30°). By increasing the conveyor rotational speed the capacity increased up to an optimum value, and further increases in rotation speed decreases capacity with average percentage of 3% for every 100rpm increases in conveyor velocity. Also, the volumetric efficiency by changing inclination angle had no affect with influencing the screw rotation speed. Generally *Srivastava et al. (2006)* mentioned that the screw conveyors performance, could be characterized by its capacity, volumetric efficiency, and power consumption, are affected by the conveyor geometry and size, the properties of the conveying materials,

and the conveyor operating variables such as, the screw velocity, screw pitch and conveying inclination angle that agreed with, Athanasiov *et al.* (2006) which reported that screw conveyors vary in diameter size from (75 to 400 mm) and length from (1 to 30 m). Screw conveyors are common devices for conveying agricultural products. The screws used for free flowing bulk solids, giving better throughput control and providing clean environmentally system for handling grains owing to their simple form, high performance, less price and maintenance. Also, Zareiforouh *et al.* (2010) They designed a special screw conveyor for rice specie called Hashemi and reported that the specific power requirements increased of the conveying screws by increasing the screw clearance and screw velocity. Also, the actual volumetric capacity increased up to a maximum value by increasing rotational conveyor screw conveyor rotational speed. Whereas, Araghi *et al.* (2010). reported that also that physical and mechanical properties of different rice species are important in maximum designing for handling processes. Conveying capacity and specific energy requirements of screws with respect to the influence materials properties' are quite differed from those of agric. grains products.

The second biological part: related to the researchers that had been studied the effects of packing operations on workers' health: As well as, Long *et al.* (1998) stated that the unhealthy environment in fields grow persons diseases and also affect their performance. They reported that air pollution contributes with the respiratory diseases such as eye irritation, bronchitis, emphysema, and asthma etc. Whereas, Khoder and Abdel\_Hammed. (1999) mentioned that during harvesting and post harvesting seasonal operations, farmers, workers and residents are exposed to high levels of organic dusts pollution. This caused adverse health diseases and also, Davis and Gulson (2005) reported that dusty granules with a diameter over than 10 µm inhalation may cause irritation of upper respiratory system. Besides, dust granules with a diameter less than 10 mm can path through the pulmonary air bags and lower respiratory tract and. As well, Puttewar and Jaiswal (2014) They evaluated the consumed energy expenditure values assessment of the labors that showed negative attitude. They reported that manually packing discomfot pains and increased heart rate and blood pressure, (MSD) musculoskeletal disorders especially to the spine area, and backbone pain when packing paddy rice sacs over than 8-10 h/day in awkward postures. However, Ahinsa, (2014) reported that such rice species covered with small needle like hairs that project outward as sharp, elongated spines. The structure of these spikes responsible for the harmful effects of hematological disorders of the rice husk dust exposure.

**MATERIALS AND METHODS**

A self-propelled machine was designed and manufactured locally to combine the traditional operations of grains handling by lifting the dried grains

from the ground, weighting accurately, packing and tying sacks mechanically combined in one machine instead of doing these labor tasks manually. A transmission system and steering devices were adjusted to fit quick movement and easily maneuver through packaging the dried grains. A suitable operation width of 1.0 m was chosen to fit small areas.

The manufactured machine consisted of the following: as shown in Figs. (1 and 2) and the schematic drawing Fig. (3). The new machine specifications are listed in table (1).

**Table.1. The new machine specifications.**

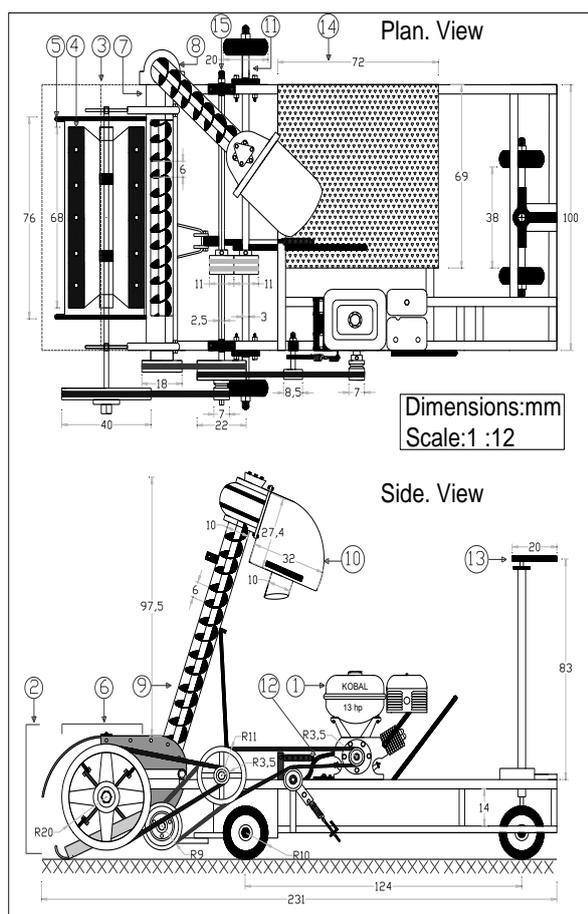
Power source	13 hp gasoline engine		
Forward speed	With load: 0.1 to 0.5 km/h Without loads:0.5 to1.2 km/h		
Chassis dimensions	width	Length	height
	120 cm	231 cm	137 cm
Operation width	100 cm		
Net weight	220 kg		
Max. productivity	0.59 to 1.57 ton/h		
Max.volumetric capacity	10.06 to 72.04 kg/min		
Consumed power	0.68 to 1. 26 Kw.h/ton		



**Fig. 1. The innovated packing machine right side and rear view.**



**Fig. 2. The innovated packing machine left side and front view.**



**Fig.3. Schematic drawing for the innovated new packing machine.**

(1-Gasoline motor, 2- picker header, 3- winnower, 4- rubber sheets, 5- shovel curved plates, 6- dust protection, 7- the horizontal screw, 8- the grains differential, 9- the inclined vertical screw, 10- the grains reservoir, 11- the front wheels, 12- the tension interlock pedal, 13-the rear guide, 14- the packing mat, 15- the idler shaft.)

**1-The motor:** gasoline motor with the following specifications as shown in table (2):

**Table. 2. The gasoline engine specifications.**

<b>Power</b>	13 hp (9.694 Kw)
Net weight	31 kg
Torque	22 n.m
Rotational speed	900,1200, 2900 and 3500 rpm
Model	Kopel (China)

**2- The picker header:** this part lifts the grains from the surface of the ground or from the drying placemats. As shown in schematic drawing (Fig. 3, No.2), the front pickup header consists of the following parts:

A- The winnower: as shown in (Fig. 3, No.3) has four axial blades with the length of 68 cm which, rotate anti clockwise by their own driving shaft with 40 cm pulley diameter to sweep the layers of grains from the ground with suitable adjusted rotational speeds differed by changing four pulleys on the idler shaft with diameters of (5, 6, 7 and 8 cm) respectively. Rubber sheets: four rubber sheets were margined with the picker blades of the winnower to sweep

smoothly the grains into the near elevator part without damage it ,as shown in (Fig. 3, No.4).

B- The shovel curved plates: which collected the accumulated grains to raise it to the elevator part with width of 76 cm and two sides of 10 cm height. Also a twine stop parts were welded to drag out the picker header in face of the grains to avoid the resistance friction as shown in, (Fig. 3, No.5).

C- The dust protection: the entire picker header was covered from its sides and top to keep the rising dusts through away the picked grains, as shown in (Fig. 3, No.6).

**3- The elevator screws:** this mechanical elevator was settled directly at the end of the edge of the rubber sheets for the winnower blades to receive and convey the picked grains. This unit consists from the following:

A- The horizontal screw: as shown in (Fig. 3, No.7) which, elevates the swept grains from the picker header to convey it horizontally by the horizontal fixed screw that, fixed axially from the left side of the machine by a special sufficient differential to the second merged inclined vertical screw. The flight diameter of the screw was 10 cm and the shaft diameter was 2.5 cm with the length of 100 cm. Where the screw pitch was changed experimentally three times (6, 7.5 and 9 cm). Also, the weight and height of the horizontal elevator screw from the ground to the chassis was settled to make balance in the front of the machine

B- The grains differential: it has two bevel gears covered centrally and attached the two ends of the screws by its inlet serrated teeth. The lifted grains discharged through it up to the vertical inclined screw pipe. In order to; release the grains compacting sometimes two merged pivotal doors from the outer sides of it attached to be opened as shown in (Fig. 3, No.8).

C- The inclined vertical screw: as shown in (Fig. 3, No. 9) which, raises the conveyed grains to the grains reservoir that fixed with inclination angle of  $45^{\circ}$  from the horizontal and fixed above over the packing mat for smooth sac filling. The holding screw pipe position was calculated geometrically to make balance for the machine and also suits the common height of the laborers. The dimensions of the inclined vertical screw was {10, 2.5, 120, and (6, 7.5 and 9) cm} for the screw flight diameter, shaft diameter, shaft length and the variable screw pitches respectively.

D- The grains reservoir: it was suited with its sack holders to be in the line with the raising quantities of the conveyed grains. The reservoir geometric dimensions were (27.4×34 cm), as shown in (Fig. 3, No.10). Also, a lateral door was merged to it from the side to control the packing operation.

**4- The chassis:** it was manufactured with length of 231 cm to suit the topography of the soil as possible to avoid curves and get well smooth operating as been designed. The operating width was settled at 100 cm to fit common possessions and to easier turning the machine. The chassis was formed from 2 cm square iron pipes to

sustain the different loads of; sacks, operator and motor weight. The center of gravity was limited mathematically which, lies under the outlet pipe of the grains reservoir on the chassis so the front weight of the pickup header equalized with the variable loads, that made the steady balance. The chassis consisted from the following:

- A- The traction front wheels: two pressed wheels of 25 cm diameter were fixed on 35 mm diameter shaft which fixed by two flanges bears on the chassis to let the driving shaft rotor by the double fixed 11 cm pulley diameter with two V shape belts of (13×1250 mm) thickness and length, as shown in (Fig. 3, No.11).
- B- The tension interlock pedal: it was fixed inferiorly to mesh the 11 cm twine pulley on the idler shaft that connected by a double V shape belts (13×1000 mm) thickness and length to the motor. A strength spring, as shown in (Fig.3, No.12) was fixed to be used by the operator to move or stop the machine movement
- C- The rear guide: the steering arm with length of 83 cm was fixed to rear driving the machine by the same two wheels with 38 cm axe length. The rear wheels can round 360 degree to make the more convenient efficient, as shown in (Fig. 3, No.13).
- D- The packing mat: it was settled with dimensions of (72×96 cm) to suit the cylindrical shape of the sacks and the operator too. It was made of 5 mm iron crimped sheets and ripped inferiorly to stand heavy loads, as shown in (Fig. 3, No.14).

**5- Attaching devices:**

- A- Digital scale: it was installed on the packing mat under the grains reservoir to measure accurately the packing grains directly with the same weight as desired, as shown in Fig. (4). A small buzzer was connected to the scale to horn the operator when the desired sack weight reached.
- B- Sacks tying device: with recharged built-in battery to tie and close the packed sacks,as shown in Fig. (5).



**Fig.4. The digital scale. Fig.5.The sacks tying device.**

**6- The power transmission system:**

The power transmitted, as shown in Fig. (3) from the motor pulley of 7 cm diameter to the idler hexagonal shaft (Fig.3, No.15) with the side 22 cm pulley to the 18 cm Dia. for the elevating screws unit shaft and also the 40 cm Dia. of the winnower shaft. Also, two belt tensions were adjusted to the transmission system. All the movement parts and speeds are listed in table (3).

**Table. 3. The rotating pulleys speed.**

Rotating pulleys		Dia. cm	Dia. cm	Speed, rpm		Speed, m/sec	Reduction ratios	Speed ratio between (winnow : screw)
From:	to							
Motor pulley	Inner idler pulley	7	22	900	286.36	3.30	1 : 0.32	
				1200	381.82	4.40		
				2900	922.73	10.63		
				3500	1113.64	12.83		
Inner idler pulley	Screws pulley	22	18	286.36	350.00	3.30	1 : 1.22	
				381.82	466.67	4.40		
				922.73	1127.78	10.63		
				1113.64	1361.11	12.83		
Walking idler pulley	Walking pulley	11	11	286.36	286.36	1.65	1 : 1	
				381.82	381.82	2.20		
				922.73	922.73	5.31		
				1113.64	1113.64	6.41		
Outer idler pulley	Winnower pulley	5	40	286.36	35.80	0.75	1 : 0.125	1 : 9.78 (0.102)
				381.82	47.73	1.00		
				922.73	115.34	2.42		
				1113.64	139.20	2.92		
				286.36	42.95	0.90		
				381.82	57.27	1.20		
		7	40	922.73	138.41	2.90	1 : 0.150	1 : 8.15 (0.123)
				1113.64	167.05	3.50		
				286.36	50.11	1.05		
				381.82	66.82	1.40		
				922.73	161.48	3.38		
				1113.64	194.89	4.08		
8	40	40	286.36	57.27	1.20	1 : 0.175	1 : 6.98 (0.143)	
			381.82	76.36	1.60			
			922.73	184.55	3.87			
			1113.64	222.73	4.66			

**The experimental procedure**

The experiments were conducted after harvesting season of rice crop at El- Serw Agric. Res.

St. in Damietta Governorate. The common species (Giza 178 and Sakha 103) of rice respectively were chosen to conduct tests. Where, the primary

experimental tests were done to measure the bulk densities for those grains in the laboratory which, was about (640 kg/m<sup>3</sup>). The paddy was published in the station experimental yard as, the limited reviewed moisture content reached to 15 % d.b. The factorial design for the experiment was chosen to evaluate the new machine to measure the effective interaction between the tested variables as follows; four speed ratios between the winnower and the elevator screw rotational speeds as (0.102, 0.123, 0.143 and 0.164) (1: 9.78, 1: 8.15, 1: 6.98 and 1: 6.11); three screw pitches for the elevator screw as (6, 7.5 and 9 cm) and three thicknesses (5, 10 and 15 cm) for the grains layers in area of (6×10= 60 m<sup>2</sup>). The experiments were replicated three times. The data were statistically analyzed to determine the significant effect of the mentioned variables under the study according to the probability (P < 0.05) by the CoStat Program (Oida, 1997).

**Measurements**

**1- The picking efficiency (η<sub>p</sub>), %:**

It was calculated by measuring the percentage of the picking grains mass to the total mass of the published grains from the following equation:

$$\eta_{p\%} = \frac{Pm}{Tm} \times 100 \dots\dots\dots (1)$$

Where: η<sub>p</sub> : picking efficiency, % ,  
 Pm : picking grains mass, kg,  
 Tm : total grains mass on ground, kg.

**2- The theoretical volumetric capacity of the auger (V<sub>th</sub>), cm<sup>3</sup>/min:**

It was measured according to Srivastava (1993).

$$V_{th} = \frac{\pi}{4} [(d_{sf})^2 - (d_{ss})^2] I_p N \dots (2)$$

Where: V<sub>th</sub> : the theoretical volumetric capacity, cm<sup>3</sup>/min  
 d<sub>sf</sub> : screw flight diameter, cm,  
 d<sub>ss</sub> : screw shaft diameter, cm  
 I<sub>p</sub> : pitch length, cm,  
 N : screw rotational speed, rpm

**3- The volumetric efficiency (η<sub>v</sub>), %:** It was defined as:

$$\eta_v\% = \frac{V_{ac}}{V_{th}} \times 100 \dots\dots\dots (3)$$

Where: η<sub>th</sub> : volumetric efficiency, %  
 V<sub>ac</sub>: actual volume capacity, cm<sup>3</sup>/min,  
 V<sub>th</sub> : the theoretical volumetric capacity, cm<sup>3</sup>/min.

**4- The grains damage percentage (Gd), %:** It was assumed by the following equation:

$$Gd\% = \frac{W_d}{W_t} \times 100 \dots\dots\dots (4)$$

Where: W<sub>d</sub> : the damaged grains symbol weight, gm,  
 W<sub>t</sub> : total symbol weight, gm.

**5- The machine productivity (P), ton/h:** It was assumed by the following equation:

$$P = \frac{M}{T} \text{ ton / h} \dots\dots\dots (5)$$

Where: P : the machine productivity, ton/h,  
 M: packing grains mass, kg. T: packing time, h.

**6- The machine efficiency (Me), %:** It was measured according to Kepner et al. (1982).

$$M_e = \frac{T_{th}}{T_{ac}} \times 100 \dots\dots\dots (6)$$

Where: Me : machine efficiency, % , T<sub>th</sub> : theoretical time per m<sup>2</sup>, h T<sub>ac</sub> : the actual operating time, h.

**7- The fuel consumption (F), lit/min:**

Fuel consumption was determined by measuring the volume of fuel consumed during the operation time for each run and calculated in liter per hour. It was measured by completely filling the fuel tank then before each end run and refilling the fuel tank using a scaled container. The fuel consumption rate was calculated from the following equation:

$$F = \frac{V}{T} \text{ L / h} \dots\dots\dots (7)$$

Where: F : rate of fuel consumption, L/h,  
 V : rate of consumed fuel, L T: time, h

**8- The machine energy requirements (Pr), kW.h/ton:**

It was estimated by using the following equation: (Hunt, 1983)

$$Pr = \left( \frac{Fs \times \rho_f \times C.V}{3600} \right) \times \left( \frac{427 \times \eta_{th} \times \eta_m}{75 \times 1.36 \times FC} \right) \cdot \frac{1}{\rho_G} \text{ (kW.h/ton)} \dots (8)$$

Where: Pr : machine requirements, (kW.h/ton);  
 Fs : fuel consumption rate, (L/h);  
 ρ<sub>f</sub> : density of fuel, kg/L, (for diesel = 0.85 kg/L);  
 C.V : calorific value of fuel, (Kcal/kg);  
 427 : thermal-mechanical equivalent, (kg.m/Kcal);  
 η<sub>th</sub> : thermal efficiency of the engine, assumed 40 % for diesel engine; η<sub>m</sub> : mechanical efficiency to engine, assumed 80 % for diesel engine;  
 Fc : actual field capacity, m<sup>2</sup>/h. ρ<sub>G</sub>: density of paddy grains, ton/m<sup>3</sup>, (for paddy = 0.64 ton/m<sup>3</sup>);

**9- The rising dusts (D), mg/m<sup>3</sup>:** it was measured by the personal dust sampler type (PS-43: Japan) to measure the dust rate (mg/m<sup>3</sup>) for person, as shown in Fig. (6).



Fig. 6. The personal dust sampler.

**10- The cost estimation (C), L.E/h:**

The operating cost was determined using the following formula:

$$\text{Operating cost (L.E/h)} = \frac{\text{Machine hourly cost (L.E/h)}}{\text{Actual machine capacity (m}^2\text{/h)}} \dots (9)$$

The labor cost was estimated actually from comparing the labors wage currently which was about 25 L.E/ton includes packing, measuring and tying the ton of grains in comparison with the operating cost of using the innovated packing machine. However, the economic study was estimated from the rental rate , Internal Rate of Return and the capital return.

**RESULTS AND DISCUSSION**

**A- Factors affecting grains picking efficiency**

Results presented in Fig. (7) showed the relationships between speed ratio {winnower to conveyor screws Sr},

the picking efficiency ( $\eta_p$ ), at different screw pitches  $I_p$  and the paddy layers thicknesses  $L_{th}$ . Increasing the  $Sr$  increased the picking efficiency of grains with increasing the treatment of the  $I_p$  and the  $L_{th}$  in direct relationships. However, the optimum values of the picking grains efficiency  $\eta_p$  were (91.34 and 89.56 %) respectively that ranged in a direct relationship for  $Sr$  0.164 at 9 cm of the  $I_p$  and 15 cm of the  $L_{th}$ . The minimum values of ( $\eta_p$ ) percentages were (78.98 and 79.55 %), respectively under 0.102  $Sr$  at 6 cm of the  $I_p$  and 5 cm of the  $L_{th}$  respectively. These results may be attributed to increasing the speed ratio, which increased the ability of the packing machine to maximize the inlet picked grains per unit area due to increasing the paddy layers thicknesses on the ground and vice versa by increasing the conveyor screws pitches.

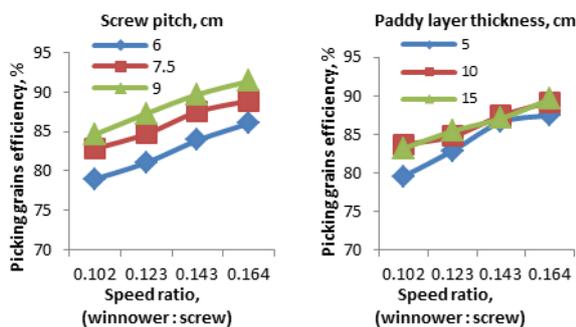


Fig.7. Effect of the speed ratio on the picking grains efficiency at the different screw pitches and paddy layers thicknesses.

Statistically, there is high significance difference between the tested factors of the picking grains efficiency  $\eta_p$ . Also, the total interaction between different treatments show a high significant effect ( $P < 0.05$ ) and ( $C.V = 1.590$ ) for the  $\eta_p$ . ANOVA analysis indicated highly significant differences between the treatments. A simple power regression analysis applied to relate the change in ( $\eta_p$ ) with the change in the tested factors for all treatments. The obtained regression equation was in the form of:

$$\eta_p, \% = 54.474 + 109.149Sr + 1.916IP + 0.219L_{th} \quad (R^2 = 0.9178)$$

**B- Factors affecting the conveyor screws volumetric efficiency**

Data illustrated in Fig. (8) appeared the relationships between speed ratio between winnower to conveyor screws  $Sr$  and the actual volumetric capacity of the conveyor screws ( $V_{ac}$ ) under different screw pitches  $I_p$  and the paddy layers thicknesses  $L_{th}$ . Increasing the  $Sr$  increased the ( $V_{ac}$ ) with increasing the treatment of the  $I_p$  and the  $L_{th}$  in direct relationships. The maximum values of the ( $V_{ac}$ ) were (72.04 and 59.68 kg/min), respectively for  $Sr$  0.164 at 9 cm of the  $I_p$  and 15 cm of the  $L_{th}$ , as well, the lowest values of the ( $V_{ac}$ ) were (10.06 and 12.54 kg/min), respectively for the 0.102  $Sr$  at 6 cm of the  $I_p$  and 5 cm of the  $L_{th}$  respectively.

Clearly, direct relationships were found between the tested factors and the measured volumetric efficiency, as shown in Fig. (9). The optimum values of the conveyor screws volumetric efficiency ( $\eta_v$ ) were (93.58 and 92.84 %) respectively, for  $Sr$  0.164 at 9 cm of the  $I_p$  and 15 cm of the  $L_{th}$ , where, the minimum values of ( $\eta_v$ ) percentages

were (76.04 and 76.03 %), under 0.102  $Sr$  at 7.5 cm of the  $I_p$  and 5 cm of the  $L_{th}$  respectively.

Statistically, there are high significance differences between the tested factors of the actual volumetric capacity of the conveyor screws ( $V_{ac}$ ) and the conveyor screws volumetric efficiencies ( $\eta_v$ ). Also, the total interaction between different treatments show a high significant effect ( $P < 0.05$ ) and ( $C.V = 0.425$  and  $0.355$ ) for the ( $V_{ac}$ ) and ( $\eta_v$ ) respectively. ANOVA showed highly significant differences between the treatments. Also, a simple power regression analysis applied to relate the change in ( $V_{ac}$  and  $\eta_v$ ) with the change in the tested factors for all treatments. The obtained regression equations were in the form of:

$$V_{ac}, \text{kg/min} = -112.142 + 816.378 Sr + 4.9126 IP + 0.0484 L_{th} \quad (R^2 = 0.9999)$$

$$\eta_v, \% = 40.0940 + 264.693 Sr + 0.926 IP + 0.111 L_{th} \quad (R^2 = 0.9986)$$

**C- Factors affecting grains damage percentage**

Fig. (10) showed the effect of the speed ratio between winnower to conveyor screws  $Sr$  and the grains damage percentage ( $G_d$ ) at the tested variables. Generally, increasing the  $Sr$  increases the grains damage percentage with increasing  $I_p$  and  $L_{th}$  with contrast relationships. The highest values of the grains damage percentages  $G_d$ , % were (2.90 and 2.84 %) respectively, by  $Sr$  of 0.164 under 9 cm of the  $I_p$  and 5 cm of the  $L_{th}$ , whereas, the minimum values of  $G_d$  percentages were (1.77 and 1.87 %), under 0.102  $Sr$  with 6 cm of the  $I_p$  and 5 cm of the  $L_{th}$  respectively. This result may be owing to the by increasing volumetric capacity of the conveyor screws the grains get moreover so it can be damaged with a less percentages for the high revolution speeds for the screws. Statistically, there is high significance difference between the tested factors and the grain damage percentage ( $G_d$ ). Also, the total interaction between different treatments show a high significant effect ( $P < 0.05$ ) and ( $C.V = 0.963$ ) for the  $G_d$ . ANOVA analysis indicated highly significant differences between the treatments. The simple power regression for ( $G_d$ ) was in the form of:

$$G_d, \% = -0.0816 + 13.950Sr + 0.0686 IP + 0.00717L_{th} \quad (R^2 = 0.98058)$$

**D- Factors affecting machine efficiency**

Fig. (11) illustrated the effect of the speed ratio between winnower to conveyor screws  $Sr$  and the machine efficiency ( $Me$ ) at the tested variables. Generally, increasing the  $Sr$  increases the machine efficiency with increasing  $I_p$  and  $L_{th}$  with contrast relationships. The highest values of the machine efficiency ( $Me$ ) were (91.11 and 90.56 %) respectively, by  $Sr$  of 0.164 under 6 cm of the  $I_p$  and 5 cm of the  $L_{th}$ , whereas, the minimum values of ( $Me$ ) percentages were (78.98 and 80.78 %), under 0.102  $Sr$  with 9 cm of the  $I_p$  and 15 cm of the  $L_{th}$  respectively. This result may be owing to the machine was designed to be self-propelled. The adequate forwards speed, the maximum volumetric capacity, less maintenance and the easy maneuver made low time losses so the field efficiency reaches high levels. Statistically, there is high significance difference between the tested factors and the machine efficiency ( $Me$ ). Also, the total interaction between different treatments show a high significant effect ( $P < 0.05$ ) and ( $C.V = 0.962$ ) for the ( $Me$ ). ANOVA analysis indicated highly significant differences between the treatments. The simple power regression for ( $Me$ ) was in the form of:

$$Me, \% = 63.9978 + 147.782 Sr + 0.25 IP - 0.00833 L_{th} \quad (R^2 = 0.964)$$

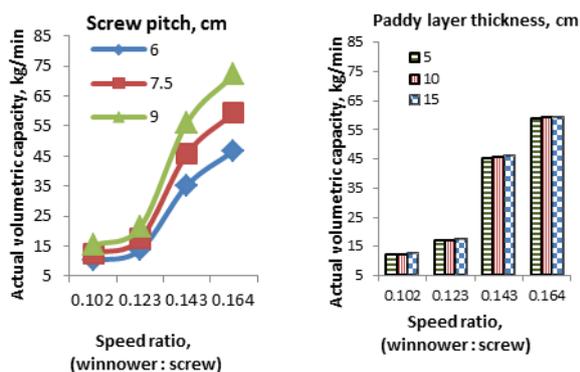


Fig.8. Effect of the speed ratio on the actual volumetric capacity of the conveyor screws at the different screw pitches and paddy layers thicknesses.

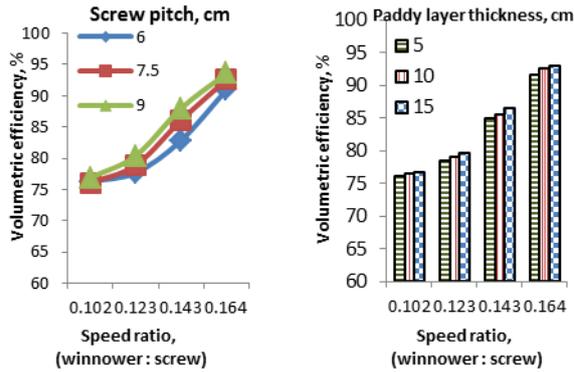


Fig.9. Effect of the speed ratio on the volumetric efficiency of the conveyor screws at the different screw pitches and paddy layers thicknesses.

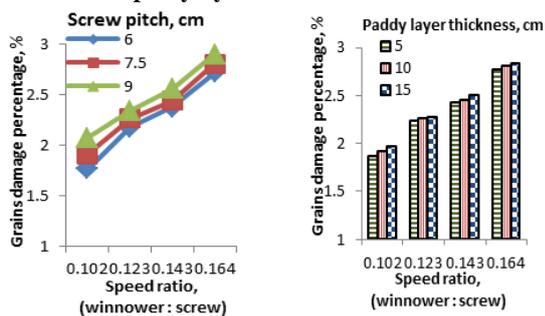


Fig.10. Effect of the speed ratio on the grains damage percentage at the different screw pitches and paddy layers thicknesses.

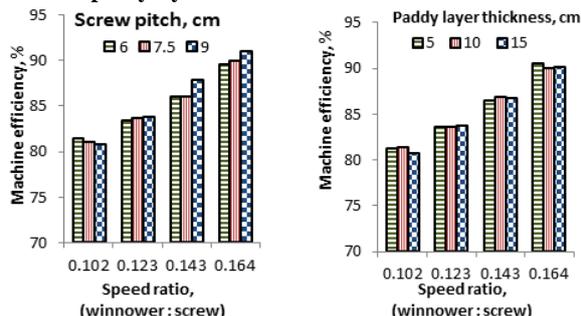


Fig.11. Effect of the speed ratio on the machine efficiency at the different screw pitches and paddy layers thicknesses.

**E- Factors affecting machine productivity**

Fig. (12) showed that there are direct relationships between the machine productivity (P) with the Sr at increasing the Ip and the L<sub>th</sub> in. The maximum values of the (P) were (1.42 and 1.57 ton/h), respectively for Sr of 0.164 at 9 cm of the Ip and 10 cm of the L<sub>th</sub>, while the lowest values of the (P) were (0.63 and 0.59 ton/h), respectively for the 0.102 Sr at 6 cm of the Ip and 5 cm of the L<sub>th</sub>. The machine productivity was multiplied may be; due to the suitable forward speed, the high volumetric capacity of the conveyor screws, the suitable operation width, using powerful auto motor, gathering many operations in one machine, using suitable rotational speeds

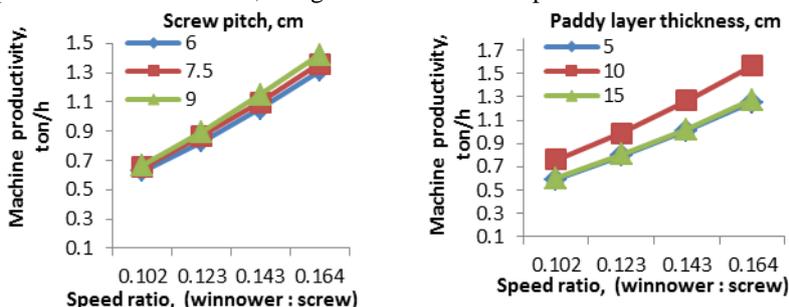


Fig.12. Effect of the speed ratio on the machine productivity at the different screw pitches and paddy layers thicknesses.

and high comfort for the operator without dusty breath. Statistically, there are high significance difference between the tested factors of machine productivity (P). However, the total interaction between different treatments show a high significant effect ( $P < 0.05$ ) and ( $C.V = 2.145$ ) for the (P). The analysis of variance viewed highly significant difference between the treatments for (P). The applied simple power regression analyses was:

$$P, \text{ ton/h} = -0.745 + 11.525 Sr + 0.0258IP + 0.001389 L_{th} \quad (R^2 = 0.9964)$$

According to the achieved formula of the machine productivity the predicted Fig. (13) proved that there aren't high differences between the measured and calculated data.

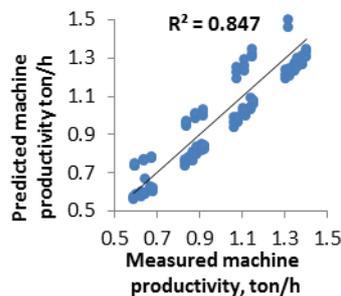


Fig.13. The measured and predicted machine productivity.

**F- Factors affecting machine energy consumption**

Commonly, the effect of the speed ratio Sr of the packing machine and the fuel consumption (F) at the different screw pitches Ip and the paddy layers thicknesses L<sub>th</sub> are illustrated in Fig. (14). Increasing the Sr increases the consumed fuel (F) with increasing the Ip and the L<sub>th</sub> in direct relationships. The maximum values of the (F) were (2.41 and 2.35 lit/h), respectively for Sr 0.164

at 9 cm of the Ip and 15 cm of the L<sub>th</sub>, while the lowest values of the (F) were (1.28 and 1.38 lit/h), respectively for the 0.102 Sr at 6 cm of the Ip and 5 cm of the L<sub>th</sub>. Data illustrated in Fig. (15) viewed opposite relationship, where the optimum values of the consumed energy (Pr) were (1.23 and 1.26 Kw.h/ton) respectively for Sr of 0.102 at 9 cm of the Ip and 15 cm of the L<sub>th</sub>, where, the lowest values of (Pr) were (0.78 and 0.68 Kw.h/ton), respectively under 0.164 for Sr at 9 cm of the Ip and 10 cm of the L<sub>th</sub>. The

obtained results could be because of regulating the machine loads, the suitable rotational speeds, the powerful engine, calculating the needed power for the machine elements, using attaching power system to power off the lads through turns, controlling the speed by the operator as the paddy layers thicknesses and adapting the economic mode of consuming fuel as need. Statistically, there are high significance differences between the tested factors of fuel consumption (F) and the consumed energy (Pr). Also, the total interaction between different treatments show a high

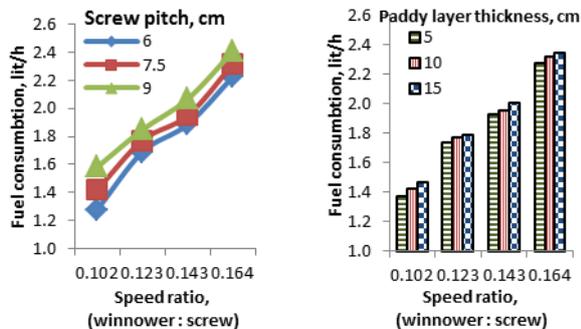


Fig.14. Effect of the speed ratio on the machine fuel consumption at the different screw pitches and paddy layers thicknesses.

**G- Factors affecting the dust rising from packing operations**

Hence, as been cleared from Fig. (16) the tested effect between speed ratio Sr of the packing machine and the mechanical packing rising dust (D) at the tested factors showed a direct data direction with increasing the Sr of the packing machine increases packing rising dust (D) for increasing the treatment of the Ip and the L<sub>th</sub>. The maximum values of the (D) were (5.18 and 5.14 mg/m<sup>3</sup>), respectively for Sr 0.164 at 9 cm of the Ip and 15 cm of the L<sub>th</sub>, besides that, the lowest values of the (D) were (1.25 and 1.35 mg/m<sup>3</sup>) respectively for the 0.102 Sr at 6 cm of the Ip and 5 cm of the L<sub>th</sub>. These results may be attributed to using closed picking system with a smart innovated winnower and a protective shield with aerodynamics forces to clear dust from paddy grains through picking it into the front picker header.

Also the closed conveying screws system which tightened well and jointed with a suitable reservoir to filter the rest dusts away from the operator. Also using suitable forward speeds minimized the rising dusts too the designed chassis height and the wheels diameter decreases the emission dusts at least. Statistically, there are high significance difference between the tested factors and mechanical packing rising dust (D). Also, the total interaction between different treatments show a high significant effect (P<0.05) and (C.V=2.693) for the (D). The analysis of variance for (D) indicated highly significant difference between the treatments. The simple power regression formula for (D) was:

$$D, \text{mg/m}^3 \text{ air} = -6.768 + 61.431 \text{ Sr} + 0.232 \text{ IP} + 0.0224 \text{ L th} \quad (R^2=0.9975)$$

**H- Factors affecting machine operating cost**

Fig. (17) displayed the relationships between speed ratio Sr and the operating cost (C) at the different screw pitches Ip and the paddy layers thicknesses L<sub>th</sub>. So, an inverse relationship of increasing the Sr of the packing

machine decreases the machine operating cost (C) with increasing the treatment of the Ip and the L<sub>th</sub> were found. The maximum values of the machine operating cost (C) were (16.10 and 16.94 L.E/h), respectively for Sr of 0.102 at 6 cm of the Ip and 5 cm of the L<sub>th</sub>, where the lowest values of the (C) were (7.12 and 6.38 L.E/h), respectively for the 0.164 Sr at 9 cm of the Ip and 10 cm of the L<sub>th</sub>. The economic data from the tested machine minimized the costs at least levels because of; the massive productivity, the large field capacity and combining multi grain operations in one decrease the total costs. Also the ability of the growers to using these new technique facilities the packing requirements as affixed assets which can be used repeatedly from sacks etc. Statistically, there is high significance difference between the tested factors and the machine operating cost (C).

$$C, \text{L.E/h} = -30.646 + 131.032 \text{ Sr} - 0.273 \text{ IP} - 0.012 \text{ L th} \quad (R^2=0.8367)$$

The total fabrication cost of the innovated packing grains machine including workshop manufacturing and attaching devises costs was about 7000 LE at 2016 price level. The innovated machine can decrease the costs of packing from (25 to 17 L.E/h) as about 30 % cost reduction ratio. The internal rate of return (IRR) after considering depreciation, alternative chance costs, the amount costs of fuel and lubricants, and the rental rate calculated found 17 L.E/ h. The internal rate of return (IRR) with release year was calculated found 32%. This rate is visible compared with the current interest rate of 16% due to the capital return which was about 3 years.

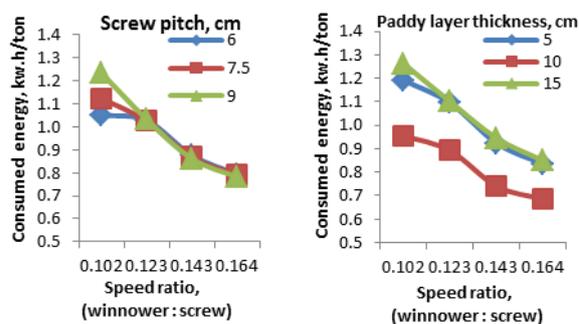
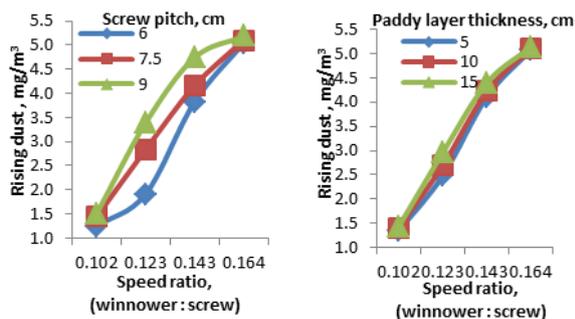


Fig.15. Effect of the speed ratio on the consumed energy at the different screw pitches and paddy layers thicknesses.

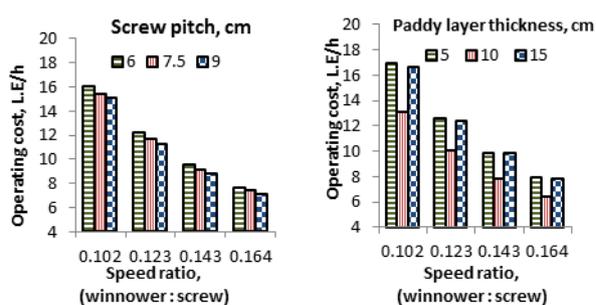
Also, the total interaction between different treatments show a high significant effect (P<0.05) and (C.V=2.125) for the (C). Highly significant difference was indicated between the treatments from ANOVA analysis. The measured power regression formula for (C) was:

$$C, \text{L.E/h} = -30.646 + 131.032 \text{ Sr} - 0.273 \text{ IP} - 0.012 \text{ L th} \quad (R^2=0.8367)$$

The total fabrication cost of the innovated packing grains machine including workshop manufacturing and attaching devises costs was about 7000 LE at 2016 price level. The innovated machine can decrease the costs of packing from (25 to 17 L.E/h) as about 30 % cost reduction ratio. The internal rate of return (IRR) after considering depreciation, alternative chance costs, the amount costs of fuel and lubricants, and the rental rate calculated found 17 L.E/ h. The internal rate of return (IRR) with release year was calculated found 32%. This rate is visible compared with the current interest rate of 16% due to the capital return which was about 3 years.



**Fig.16. Effect of the speed ratio on the packing rising dust at the different screw pitches and paddy layers thicknesses.**



**Fig.17. Effect of the speed ratio on the machine operating cost at the different screw pitches and paddy layers thicknesses.**

**CONCLUSION**

The main results could be summarized as follows:

- 1) The maximum values of the picking grains ( $\eta_p$ ) and conveyor screw volumetric efficiencies ( $\eta_v$ ) were (91.34 and 93.58 %) for Sr of 0.164 at 9 cm of the Ip and 15 cm of the L th.
- 2) The highest value of the grain damage percentage (Gd) was 2.90 % for Sr of 0.164 under 9 cm of the Ip and 5 cm of the L th.
- 3) The optimum value of the machine efficiency (Me) was 91.11 % for Sr of 0.164 at 6 cm of the Ip and 5 cm of the L th.
- 4) The highest value of the machine productivity (P) was 1.57 ton/h for Sr of 0.164 at 9 cm of the Ip and 10 cm of the L th.
- 5) The maximum value of the consumed energy (Pr) was 1.26 Kw.h/ton for Sr of 0.102 at 9 cm of the Ip and 15 cm of the L th.
- 6) The maximum value of the packing machine rising dusts (D) was 5.18 mg/m<sup>3</sup>, for Sr 0.164 at 9 cm of the Ip and 15 cm of the L th.
- 7) The optimum value of the machine operating cost (C) was 16.94 L.E/h for Sr of 0.102 at 6 cm of the Ip and 5 cm of the L th. Where, the proposed machine can decrease the costs of packing from (25 to 17 L.E) as about 30% cost reduction ratio. So the suitable operating settings for the new packing machine were: Sr of 0.164 at 9 cm of the Ip and 10 cm of the L th.
- 8) The internal rate of return (IRR) with release year was calculated found 32%. This rate is visible compared with the current interest rate of 16% due to capital return was about 3 years.

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### تصنيع وحدة ميكانيكية لتعبئة الحبوب أليا

أحمد شوقي السيد السيد، مانسة محمد منير مجاهد، يوسف يوسف رمضان و أيمن موسى عبدالعظيم  
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يعتبر محصول الأرز من أهم المحاصيل الزراعية الهامة والإستراتيجية التي تزرع في مصر ، وقد تم التغلب علي معظم المشاكل الخاصة بزراعه وحصاد الأرز إلا أنه تبقى مشكلة وهي عملية التعبئة فمزالتم يتم يدويا ( عمالة للتحميل والتعتيق والنشر للتجفيف ثم للتقليب والتعبئة والوزن والتربيط ) نظرا لقلة العمالة الزراعية حاليا والحاجة الملحة لتوفير الوقت والجهد اللازم لعملية تعبئة محصول الأرز الشعير فقد ظهرت الحاجة إلى وجود آلة مناسبة لتعبئة محصول الأرز الشعير أليا حيث يهدف هذا البحث إلي: تصميم آلة مناسبة لتعبئة محصول الأرز الشعير أليا لتخفيض التكاليف وزيادة الإنتاجية ، والتحكم في وزن الأجوالة بدون استخدام الموازين ، وزيادة نسبة النقاوة والتي تعتبر من أهم المواصفات القياسية المطلوبة عند عمليات الشراء. حيث تم تصميم آلة تتكون من الأجزاء الآتية: 1- مضرب أمامي مزود بمجموعة من الفرش الجلد لتجميع الحبوب وتوجيهها إلي مجموعة من البريمات (بريمة أفقية ورأسية) التي تقوم بنقل الحبوب إلي خزان للحبوب مزود بحامل للأجوالة لتعبئتها أليا. 2- موتور ودبرياج للآلة لتكون ذاتية الدفع لعدم إجهاد العامل والتحكم في سرعة التعبئة بها حيث تم تصميم نظام النقل اعتمادا علي سرعة التعبئة وذلك لزيادة السعة الإنتاجية للآلة. 3- ميزان ذاتي مزود بمنبه للتحكم في وزن الأجوالة أليا عند الوصول للوزن المحدد مما يوفر في الوقت والجهد أيضا. 4- جهاز تربيط كهربى لقفل الأجوالة بعد وزنها لميكنة عملية التعبئة بالكامل . 5 - حاجز واقى أمامي ومروحة لإزاحة التراب والغبار والسل المتصاعد وبعض بذور الحشائش الخفيفة لزيادة نقاوة المحصول وجودة الإنتاج والحفاظ علي صحة العامل البشرى. و يقدر العمر الافتراضي للآلة الجديدة بنحو 5 سنوات، و 500ساعة/سنة سنويا. واشتملت متغيرات الدراسة علي ثلاثة متغيرات تجريبية ومستوياتها وهي: أربعة سرعات نسبية بين المروحة والبريمات هي (0.102، 0.123، 0.143، 0.164)، وثلاثة مستويات من خطوة البريمة هي (6، 7.5، 9 سم)، وثلاثة مستويات من سمك طبقة الشعير فوق سطح الأرض (5، 10، 15 سم). وتضمنت القياسات 1-كفاءة الالتقاط (وزن الحبوب المعبئة بالنسبة للوزن الكلي للحبوب) 2- السعة الحجمية للبريمات 3- الكفاءة الفعلية للبريمات 4- نسبة الحبوب المكسورة 5- كفاءة الآلة 6- الإنتاجية الآلة 7- معدل استهلاك الوقود والطاقة المستهلكة 8- نسبة الغبار المتصاعد من الآلة والذي يتعرض له العامل مقارنة بنظام التعبئة اليدوي 9-التكلفة التشغيلية للآلة ومعدل العائد على الاستثمار. واشتملت أهم النتائج علي التالي علي أن:- (1) كانت أعلى كفاءة النقاط للحبوب بلغت 91.34% ، وأعلى كفاءة حجمية للبريمات الناقلة للحبوب والتي قدرت بنحو 93.58% عند نسبة سرعة للبريمات 0.164 وخطوة بريمة 9 سم وسمك طبقة الشعير كانت 15 سم، (2) كانت أعلى كفاءة حقلية للآلة الجديدة وصلت إلي 91.11% عند نسبة سرعة للبريمات 0.164 وخطوة بريمة 6 سم وسمك طبقة الشعير كانت 5 سم . (3) في حين لم تتعدى نسبة الكسر للحبوب 2.9% من وزن العينات عند أعلى نسبة سرعة للبريمات 0.164 وخطوة بريمة 9 سم وسمك طبقة الشعير كانت 5 سم. (4) و قدرت أعلى إنتاجية للآلة بنحو 1.57 طن/الساعة عند أعلى سرعة للبريمات 0.164 وخطوة بريمة 9 سم وسمك طبقة الشعير كانت 10 سم. (5) بينما كان أعلى معدل للطاقة المستهلكة للآلة الجديدة 1.26 كيلووات ساعة / الطن عند أقل نسبة سرعة للبريمات 0.102 وخطوة بريمة 9 سم وسمك طبقة الشعير كانت 15 سم. (6) بينما كانت أعلى نسبة لانبعث للأتربة عند التعبئة الألية مقارنة بالتعبئة اليدوية 5.18 مجم/م3 عند أعلى نسبة سرعة للبريمات 0.164 وخطوة بريمة 9 سم وسمك طبقة الشعير كانت 15 سم. (7) أما بالنسبة تكلفة تشغيل للآلة مقارنة بنظام التعبئة اليدوية كانت 17جنيه/الساعة عند أقل نسبة سرعة للبريمات 0.102 وخطوة بريمة 6 سم وسمك طبقة الشعير كانت 5 سم. (8) قدر معدل العائد على الاستثمار بنحو 32% ، و قدرت فترة استرداد رأس المال بحوالي 3سنوات تقريبا. ومما سبق يتبين أن أفضل معاملات لتشغيل الآلة هي نسبة سرعة للبريمات (0.164) وخطوة بريمة (9 سم) وسمك طبقة الشعير كانت (10 سم) .لذلك نوصي بالتوسع باستخدام الآلة الجديدة وعمل برنامج إرشادي متكامل للمصنعين المحليين لعرض مميزات المتعددة لنشرها علي المستوي المحلي وذلك لتشجيع التصنيع المحلي للآلات وزيادة الإنتاجية الزراعية وبالتالي زيادة الدخل القومي .