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Developing a Grading Machine for Eggplant

Amin, E. E.; T. H. El-Shabrawy and Shaimaa I. A. ABD RABO
Agric. Eng., Dept. Fac. of Agric. Mansoura Univ., Egypt.

ABSTRACT

A small grading machine was developed, fabricated and evaluated technically and economically acts by using cylinder system of rod for grading system for crops such as Baladi eggplant variety be used in small horticultural holdings, small grading stations and small factories. Series of experiments were carried out to study effect of some parameters such as rotary speed of grading unit (0.31; 0.41; 0.59) m/sec and slope angle of grading unit (0.0; 1.0; 2.0; 3.0 deg.) on grading machine capacity (ton/h), grading efficiency (%), mechanical damage of eggplant (%), specific energy consumption (kW. h/ton) and total operation cost (LE / ton) to evaluate the grading prototype. The optimum results were obtained at rotary speed 0.41 m/sec and grading slope angle 2.0 degree. At above variables the grading efficiency recorded 84.6 %, damage index of 2.71%, specific energy consumption of 0.32 kW. h/ton and total productivity cost for one ton was 5.62 LE / ton for Baladi eggplant variety.

INTRODUCTION

In Egypt, The cultivated area of vegetables crops is 759.683 thousand feddans that produces 8.33 million tons /year, (Ministry of Agricultural and Land Reclamation, 2015). Eggplant (Solanum melongena l.) is the fifth most economically important Solanaceous crop after potato, tomato, pepper, and tobacco, (Taher, et al., 2017). Egypt produces about 1 million ton /year of eggplant, (FAO, 2018).

USA standards for eggplant grades, (2013) mentioned that the largest eggplant diameter considered the main parameter affecting on grading. Eggplant sizing can be determined in terms of count minimum diameter or diameter range in the container. Eggplant packed must be reasonably homogeneous, unless the diameter range is specified.

Ukey and Linde, (2010) developed a sapota fruit grader to increase the output of fruit grading and save time and labor. A sapota fruit grader based on divergent roller type principle was designed and developed. The best combination of roller speed, its inclination and roller gap was found to be 223 rpm, 4.5 and 38 to 64 mm, respectively for highest efficiency of 89.5%. The capacity of machine was 1440 kg/h.

Amin, (1994) developed and tested a classification system consisting of a rotor cylinder and a perforated handle for the classification of potatoes, onions and oranges, The results showed that, crop parameters such as tuber dimensions and mass and machine performance such as cell area, shape, drum speed, and cylinder axis slope angle and the length of the cylinder were a significant impact on the efficiency of the staging. He adding that, the prototype efficiency was at drum speed of 25 rpm; zero sloping degree; feeding rate 1.2 kg/h which caused tuber damage of 0.23%.

Prasad, (2015) mentioned that the post-harvest losses for eggplant Okra and tomatoes ranged from 25.2 to 40.4. 23.9 to 31.5 and 19.5 to 31 %, respectively. There was a total average post-harvest loss of 32.8% for eggplant and 27.5% for the okra and 25.8% for the tomatoes along the post-Harvest series. The post-harvest loss resulting from the experimental was relatively similar at 7.8% and 8.7% for the eggplant and okra, respectively.

The objective of the present study is to develop, fabricated and evaluate technically and economically a grading machine acts by rotary cylinders for grading system. The developed grading machine is to be used in small horticultural holdings, small grading station and small food factories.

MATERIALS AND METHODS

The developed machine

The proposed grading machine used in this study was developed, installed and tested at the workshop of Mit Ali, Mansoura, Egypt. The experiments were carried out on Baladi eggplant variety. The specific of grading machine elements as presented in Figures (1 and 2) consists of five main parts as follows:

1. **Main frame** was constructed form steel angle (4 × 4 cm), 0.5 cm thick welded together with dimension of 320 cm length, 68 cm width and 100 cm height. All parts of the machine are connected on the frame in alignment.
2. **Feeding unit** is hopper with movable gate to control the amount of eggplant flow rate from the hopper. The hopper has dimensions of 100 × 65 × 34 cm for length, width and height respectively. The hopper slope angle gradually to allow sliding of eggplant and keep continuous flow at constant rate from hopper to rotary brushes unit. The hopper is supported at the frame with screw bolts.
3. **Cleaning unit contains 4 cylinder brushes.** The four brushes act as impurity separators. Each brush is of 47 cm length and 7.5 cm diameter.
4. **Grading unit having six cylinders.** Each cylinder is of 47cm length and 7.5 cm diameter. The distance between the cylinder can adjusted according the grading vegetable size. Grading unit having 6 cylinders with inter spacing. This spacing can be regulated under grading to receive the graduated eggplant.
5. **Power transmission**

The power transmission of grading machine consists of two motions; the first to vibrate the machine frame. This motion supply from the motor have 0, 18 kW. The pulley with 100 mm diameter fixed on the motor shaft. The second motion was done to rotate the grading cylinders. Using a motor having 0, 63 kW. The drive gear is connected on the motor shaft as shown in figure (3).

Experimental conditions

The experiments were designed and carried out to study the effect of the following variables:

1- Three different rotary speed of grading unit (0.31; 0.41; 0.59) m/sec.
2- Four different grading slope angle of grading unit (0.0; 1.0; 2.0; 3.0 deg.) with three receiving units.

Experimental procedure

The eggplant was let to pass on the cleaning unit to improve the product appearance and edibility and then, dropped from the cleaning unit to the grading unit. The grading unit having six cylinders and gate having six receiving unit the distance between cylinders calculate from physical properties were used to receive the graduated eggplant by shape and size.

No.	Part name
1	Main frame
2	Hopper
3	Hopper gate
4	Cleaning unit
5	Grading unit
6	Receiving unit
7	Receiving cover
8	Gear box covers
9	1st Electric motor
10	2nd Electric motor

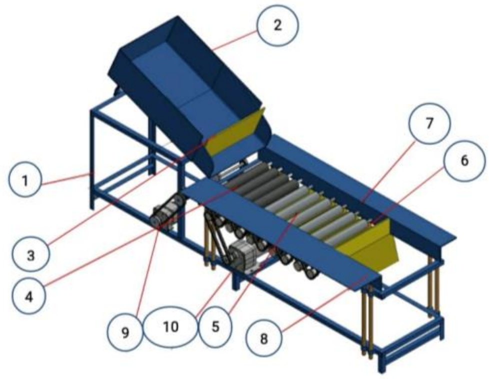

Fig. 1. An isometric of proposed machine

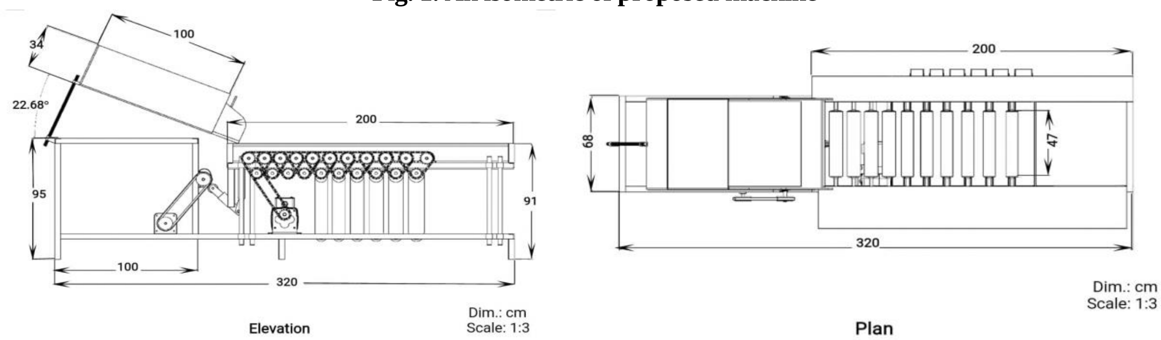

Fig. 2. Schematic diagram of the grading machine

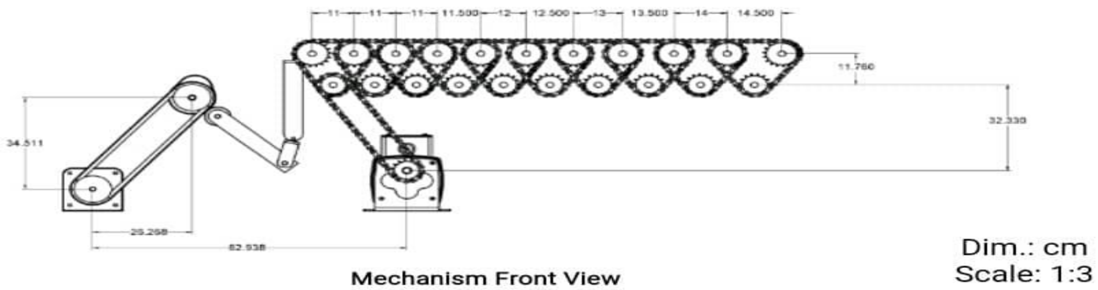

Fig. 3. The transmission system of the machine

Measurements

Fruit principal dimensions

A sliding caliper accurate ±0.01 mm was used to measure fruit length (L) and greatest diameter (D). Sphericity was then calculated according to Mohsenin, (1986) as follows:

$$S = Length / Diameter \quad .... (1)$$

If the sphericity (S) is less than 0.9, that means the fruit belongs to the oblate group. If sphericity (S) is greater than 1.1, that means the fruit belongs to the oblong group.

Measurements of fruit mechanical properties

a. Eggplant firmness

The fruit firmness was measured for eggplant using a portable hand-held tester (Taylor Pressure tester) the firmness apparatus and penetrates the fruit texture by apparatus cone and recording the fruit firmness.

b. Coefficient of friction

Coefficient of friction for eggplant was measured under the conditions of one surface nickel chrome (3 mm thickness) by placing the eggplant one by one on the horizontal surface of the inclined plane and gradually increasing the angle of surface inclination.

c. Impact heights of eggplant

Impact heights of eggplant were conducted by free fall dropping of the sample from height on Nickel chrome surface (3 mm thickness).

Measurements of mechanical damage

The mechanical damage of eggplant crop has calculated according to Mcgechan, (1980) as:

$$M_{dam} = \frac{m_1 - m_2}{m_1}, \% .... (2)$$

Where:

m_1 = Total mass before all treatments, kg,

m_2 = Total mass after treatments (undamaged fruits), kg.

The amount of damage for eggplant was determined based on the surface damage and internal bruising.

Machine grading capacity and efficiency

The grading capacity for the developed grading machine was determined according to Amin, (1994) as:

$$W = m_i \times \frac{60}{t} \quad .... (3)$$

Where:

W= Grading capacity of the machine in ton/h,
m_i = Mass of classified fruits from any unit (i) in ton,
t = Grading time in min.

The total machine grading efficiency of the machine was estimated using the following formula:

$$\eta_0 = \frac{m_1 + m_2 + m_3 + m_4}{m} \times 100 \quad \text{.......... (4)}$$

Where:

η_0= Total machine grading efficiency %,
m = Total mass of fruits in ton,
$m_{1,2,3,4}$= Averaged means difference sizes (small, medium and big in kg).

Estimation of specific energy consumption

The specific energy consumption (S.E.C.) in kW. h /ton was calculated by using the following equation:

S.E.C. = Power/ Capacity, kW. h/ ton …………. (5)

Where:

S.E.C. = Specific energy consumption, kW. h/ ton,
P= Power requirement to doing the handling process for fruits, kW,
C= Capacity of the handling machine, ton/h.

Cost evaluation for the developed grading machine

In this study two parameters were calculated as the absolute total cost including both fixed and variable costs per hour according to (ASAE, 2001) and price level of 2017.

Total operation costs (LE / h) = Fixed costs (LE / h) + variable costs (LE / h)……. (6)

Total productivity cost, (LE/ ton) = total operation costs, LE/h / capacity (optimum), ton/h…. (7)

RESULTS AND DISCUSSION

1- Physical principal dimensions

Data in table (1) shows some of the physical properties of the Baladi eggplant variety.

Table 1. Physical properties of Baladi eggplant variety:

Variety	Feature	length, mm	Diameter, mm	Volume, cm^3	Sphericity
Baladi eggplant	Max	78.43	45.18	785.23	1.36
	Min	127.99	54.46	1613.1	2.38
	Av	165.25	72.97	2853.87	3.47
	± SD	19.57	6.25	463.98	0.44
	CV %	8.45	11.68	6.15	7.82

From the data listed in Table (1), and with respect to the sphericity as shown in figure (4), it is clear that the sample of the eggplant were described as oblong variety. These result help in designing of the hopper gate to control eggplant feeding rate, division of samples into categories and determine the suitable distance between rolling to complete the grading process.

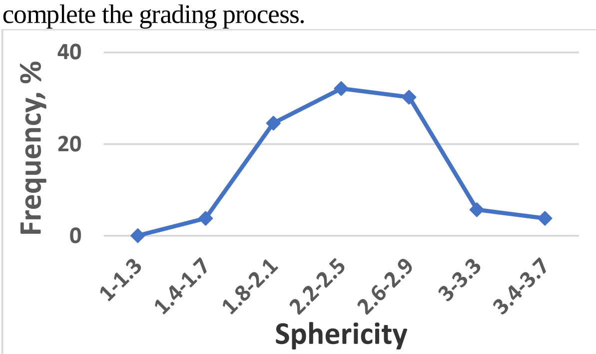

Fig. 4. Frequency of sphericity for Baladi eggplant variety

2-Mechanical properties

The mechanical properties of the studied variety of eggplant listed in table (2).

Table 2. Mechanical properties of Baladi eggplant variety:

variety	Impact		Friction	Firmness, N	
	Drop height, m	Fruit bruised, %	slope angle, deg. Nickel chrome	Surface, N Average	without the peel, N Average
Baladi eggplant	0.34	0	22.68°	5.6 ± 0.67	4.5 ± 0.6
	0.38	0			
	0.42	0			

The results indicated that the maximum and minimum impact height causing no damages on fruits. The results show that, the nickel chrome surface gave the values of friction coefficient of 0.42 m. The angle is calculated from the best height allowing the eggplant to roll easily. The angle of surface inclination of 22.68 degree. Firmness for surface is 5.6 N for eggplant.

3-Machine performance evaluation for Baladi eggplant variety

These experiments which were carried out on the developed machine to evaluate performance of machine included productivity, grading efficiency and total mechanical damage and as effected by rotary speed (m / s) and grading slope angle (deg.).

1- Capacity of the developed grading machine for Baladi eggplant variety

Data in figure (5) shows that rotary speed of 0.41 m / s tends to increase grading capacity to 3.4 ton / h at grading slope angle (0.0 deg.), rotary speed of 0.31m / s caused to decrease machine grading capacity to 1.5 ton / h at grading slope angle (0.0 deg.).

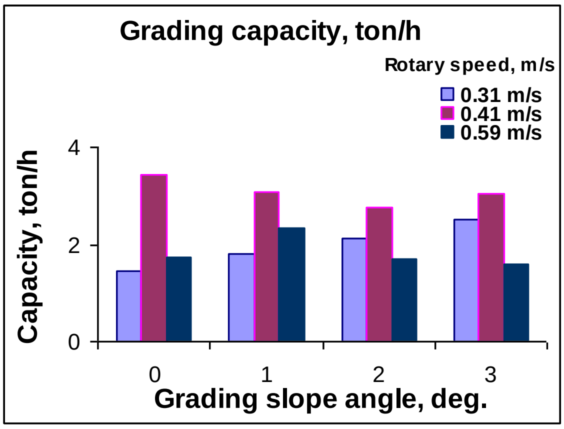

Fig. 5. Effect of rotary speed and grading slope angle on grading capacity for Baladi eggplant variety

2-Grading efficiency of the developed grading machine for Baladi eggplants variety eggplant

a. Effect of grading slope angle

Increasing grading slope angle from (0.0 to 3.0 deg.) caused to increase machine grading efficiency at different diameters of eggplant. Rotary speed of 0.41 m/s tends to increase grading efficiency to 84.6% at grading slope angle of 2.0 deg. as shown in figure (6).

b. Effect of rotary speed

Increasing rotary speed from 0.31 to 0.59 m/s caused to increase machine grading efficiency at different diameters of eggplant. Rotary speed of 0.41 m/s tends to increase grading efficiency to 84.6% at grading slope angle of 2.0 deg. as shown in figure (7).

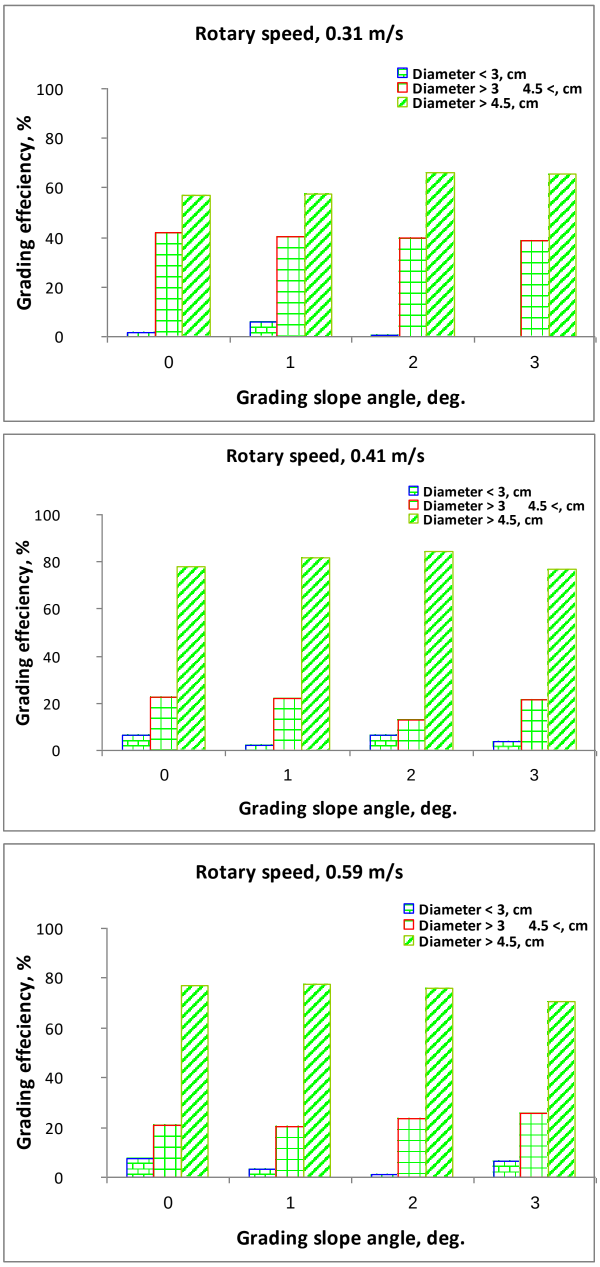

Fig. 6. Effect of grading slope angle on grading efficiency for Baladi eggplant variety

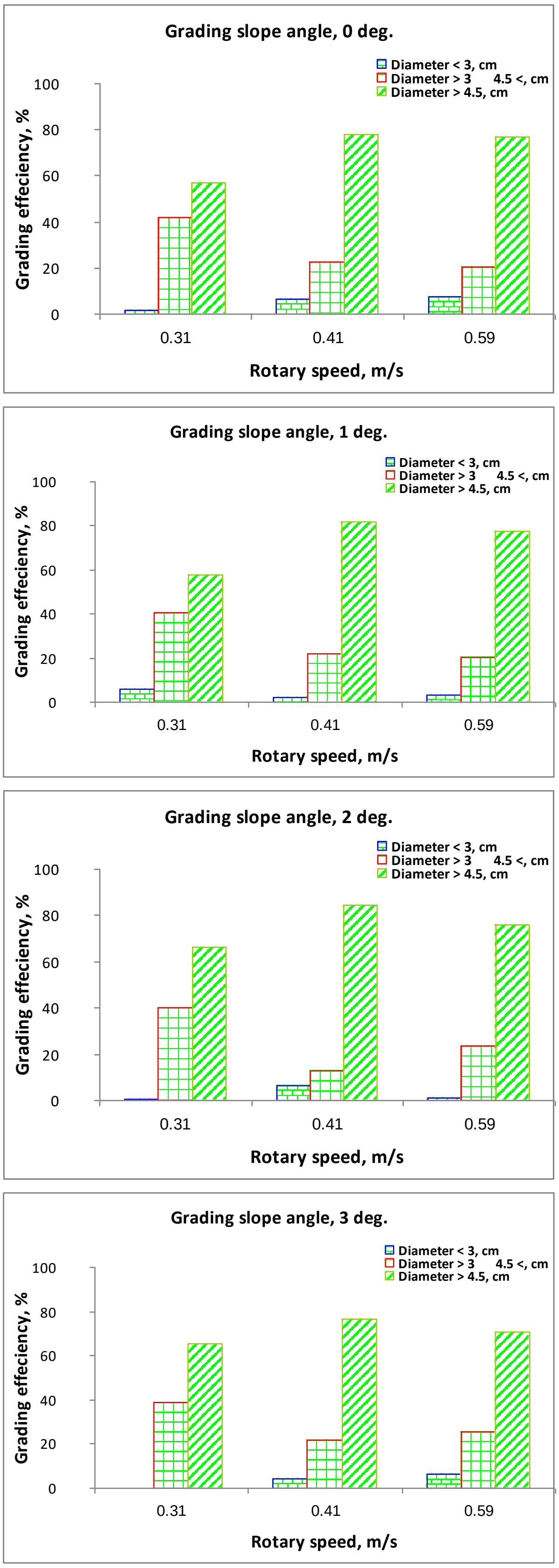

Fig. 7. Effect of rotary speed on grading efficiency for Baladi eggplant variety

4- Mechanical damage for Baladi eggplant variety

From the data illustrated in figure (8) we can see that increasing the rotary speed from 0.31 to 0.59 m/s caused a corresponding decrease mechanical damage of machine. Rotary speed of 0.41m/s tends to decrease the damage index to 2.71% at grading slope angle of 3.0 deg. during grading processes.

5- Power and energy requirements for Baladi eggplant variety

The highest specific energy consumption was recorded using highest rotating speed of rotary 0.59 m/sec which was 0.52 kW. h /ton at grading slope angle (3 deg.) while the lowest specific energy consumption was recorded using lowest rotating speed of rotary 0.31 m/sec which was 0. 32 kW.h/ton at grading slope angle (3.0 deg.) as shown in figure (9).

6- Cost estimation for the developed grading machine

Data in table (3) evident that the mechanical grading needed the lowest labour time (h/ton) while the higher labour time was obtained when the work was done manually. For it can be seen that using mechanical method for grading needed 0.4 h/ton. While the conventional grading method needed one hour per ton by using (10) workers. On-the other words, the labour time (h/ton) of manual grading is about 3.4 times larger than that using mechanical grading.

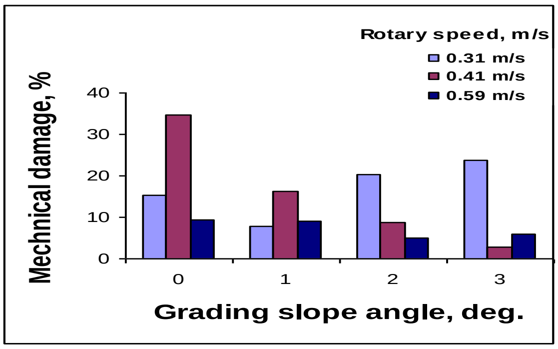

Fig. 8. Mechanical damage caused by the grading unit for Baladi eggplant variety

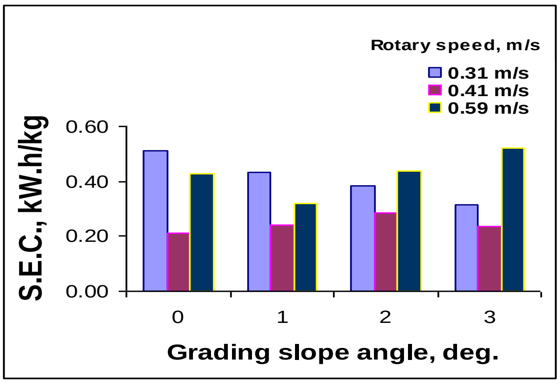

Fig. 9. Effect of grading slope angle deg. on the specific energy consumption (S.E.C.) for grading machine of Baladi eggplant variety

Table 3. Cost estimation for the developed grading machine:

No.	Items	Cost
1	Total fixed costs, (LE/h)	2.128
2	Variable costs:	
3	Repair and maintenance, (LE/h)	1.44
4	Electric energy cost, (LE/h)	0.46
5	Labour cost, (LE/h)	15
6	Grease and daily services, (LE/h)	0.08
7	Total variable costs, (LE/h)	16.98
8	Total operation cost, (LE/h)	19.108
9	The total productivity cost, (LE/ton)	5.62

CONCLUSION

The developed grading machine has good performance data in eggplant grading process with different factors under study.The optimum operating parameters for developed grading machine were rotary speed of 0.41 m/sec and grading slope angle of 2.0 (deg.). At these levels maximum grading efficiency 84.6%, damage index of 2.71%, specific energy consumption of 0.32 kW. h / ton and total productivity cost of 5.62 LE / ton for Baladi eggplant variety.

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تطوير آلة لتدريج الباذنجان

عماد الدين أمين عبد الله ، طارق حسني الشبراوي و شيماء إبراهيم عبد القادر عبدربه
قسم الهندسة الزراعية – كلية الزراعة – جامعة المنصورة.

يعتبر الباذنجان من المحاصيل التى تزرع بجمهورية مصر العربية بإجمالى انتاج مليون طن / سنة و يستخدم الانتاج للاستهلاك المحلى و جزء للتصدير مما يستوجب بعض العمليات مثل التدريج لذلك تم تصنيع و تطوير الآلة من خامات محلية فى ورشة بميت على فى المنصورة لتدريج الباذنجان البلدى بنظام الاسطوانات الدوارة لتناسب ظروف العمل فى محطات التداول ومصانع الأغذية الصغيرة. و قد تمت الدراسة على النحو التالى: (1) دراسة الخواص الطبيعية والميكانيكية لثمار الباذنجان لتحديد العوامل التصميمية للآلة . (2) دراسة العوامل الميكانيكية لتشغيل الالة . و قد شملت الدراسة المتغيرات التالية :1 . ثلاث سرعات دورانية مختلفة لأسطوانات وحدة التدريج (0.59 ;0.41 ;0.31) م / ثانية.2 . أربعة ميول مختلفة من وحدة التدريج (3.0; 2.0; 1.0; 0.0) درجة مع 3 وحدات استقبال. هذا وقد تم اختبار وتقييم أداء و كفاءة آلة التدريج المصنعة محليا تحت ظروف التشغيل المختلفة. مع تقدير احتياجات آلة التدريج المصنعة محليا من الطاقة و تقدير التكاليف لآلة التدريج. ويمكن تلخيص أهم النتائج هذه الدراسة فى النقاط التالية:1 . أكبر سعة تدريج أمكن الحصول عليها بنسبة 3.4 طن / ساعة وذلك باستخدام السرعة الدورانية 0.41 متر / ثانية.2 . بزيادة ميل وحدة التدريج من 0.0 الى 3.0 درجة يؤدي الى زيادة كفاءة التدريج عند السرعة الدورانية 0.41 متر / ثانية بنسبة 84.6 %.3. السرعة الدورانية 0.41 متر / ثانية تؤدى الى خفض مؤشر التلف للثمار بنسبة 2.71 % عند ميل 3 درجة. 4. أعلى استهلاك للطاقة النوعية سجل عند أعلى سرعة دورانية وهى 0.59 متر / ثانية بنسبة 0.52 كيلو وات .ساعة/طن بينما أقل استهلاك للطاقة النوعية سجل عند أقل سرعة دورانية وهى 0.31 متر / ثانية بنسبة 0.32 كيلو وات .ساعة / طن.5 . تبلغ إجمالى تكاليف العملية للطن الواحد 5.62 جنية / طن.6 . العوامل المثلى لتشغيل الآلة كانت باستخدام ميل التدريج 2.0 درجة و السرعة الدورانية 0.41 متر / ثانية حيث أعطت أعلى كفاءة تدريج بنسبة 84.6 ٪ ، ونسبة تلف مسموح بها إلى2.71٪ ، وكان استهلاك الطاقة المحددة 0.32 كيلووات. ساعة / طن والتكاليف الإجمالية للطن الواحد 5.62 جنية / طن للباذنجان صنف البلدي و توصى الدراسة بإستعمال المعاملات التى حققت أعلى كفاءة فى عملية التدريج.