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Development and Evaluation of a Simple Grading Machine for Okra Pods

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ABSTRACT

It will be helpful for farmers and market dealers to determine their prices by more accurate ways accepted to the consumer. So grading plays an active role in the marketing attractiveness. The main objective of this study was to develop, test and evaluate a small grading machine of okra pods to suitable for small Egyptian growers. Two machines parameters each of four levels were studied such as fruit feeding rates (350, 400, 450 and 500 kg/h), speed of reel sizer 20, 35, 50, and 65 rpm (0.419, 0.733, 1.047 and 1.361 m/s), and two types of mesh shape (square cells and parallel bars cells) on the machine grading capacity (kg/h), and efficiency (%). The mechanical damage percentages of okra pods were also determined. Results showed that this machine is quite successful for grading okra crop. The best result was obtained at 400 kg/h fruit feeding rate, and 35 rpm reel speed using parallel bars cell shape. At these levels the maximum grading efficiency of 95.2 % were obtained with machine grading capacity of 331 kg/h . At the same feeding rate 400kg/h using square cells at rotating speed of the sieves of 50 rpm, the maximum grading efficiency of 92.6 % was obtained which coincided with machine grading capacity of 335 kg/h. The mechanical damage for okra pods under study increased when grading process was carried by square cells compared with parallel bars. Grading okra pods by the proposed machine at optimum grading conditions, produced mechanical damage lower than the limits permitted for the market (5%).

INTRODUCTION

Okra pods (*Abelmoschus Esculentus* L.) is one of the common popular eaten in Egypt. It had been used for its young green fruits in fresh, frozen, canned and dray states; okra fruit has high nutritional value. It is an important crop in most developing countries, covering approximately 4 % of the total vegetable consumption. Fresh tender pods have been reported to be rich of protein, iron, mineral, vitamin C, A and B complex,.. etc. It is also a good source of fibre as indicated in the treatment and prevention of many diseases including colon cancer. ` It mixed with other ingredients to make soup (Okra food, 2003 and Owolarafe and Shotonde, 2004). Concerning Egypt, okra cultivation succeeded in new-reclaimed area due to its limit need for irrigation water and it's growing in difficult circumstances.

Okra is an important vegetable crop commercially grown in most of the tropics and subtropics with an extension to the Mediterranean climate. It is a traditional vegetable crop commercially cultivated in West Africa, Turkey, Southeast Asia, India, the southern United States, Brazil, and northern Australia (Düzyaman, 1997). In recent years okra became more and more popular as a new alternative in market diversification in Europe. It is now available as a boiled and fried vegetable in salad bars and restaurants.

The cultivated area of okra crop is 113736 feddans, which annually produces over 454944 Mg. AOAD (2015) signed that Egypt produced about 5,517,000 Mg from okra pods.

Freezing Okra is considered one of major exportable crops in Egypt. Egypt's exports of frozen okra in 2014 amounted to about 2061 Mg for about 12 countries. In 2016, the total amount of okra exported was 35 % of the total annual production (Ministry of Agricultural, 2016).

The main purpose of grading is to segregate produce into different grades for canning and other converting process. Grading, according to well-defined national and international standards, is essential for modern marketing as pricing is tied to product quality.

Numerous researchers have designed and fabricated grading machines for grading various fruits and vegetables by shape, size, and or by weight. Grading of fruits and vegetables is an important operation affecting quality, handling and storage of produce.

Ryall and Lipton (1983) showed that machines that grade by diameter tend to have higher throughputs, to be rather less expensive for a given throughput, than those, which grade by weight. They added that sizing operations involve passing the fruits over diverging belts having holes, wire mesh belting, drop roll sizes, or volumetric size. The belts with holes and the wire mesh sizes separate the fruit into two sizes while the others provide up to five or six sizes by gradual widening of the sizing members that support the fruit. Balls (1986) reported that the size grade of an item might be determined by one, two or three linear dimensions or its mass (weight). Single dimension is determined by the minimum distance apart of a pair of parallel bars between which the produce can pass. Two dimensions are determined by the distance between the sides of a square hole or diameter of a circular hole, through which the produce can pass. The third dimension will often be taken in addition to a square or circular hole standard, by a separate measurement using parallel bar gabs.

Ladaniya and Dass (1994) stated that manual size grading was still more accurate, although mechanical grading operated at a rate of 1 ton of fruit per hour. Manually processed fruits showed higher decay as a result of bruising. Yang and Liu (1997) indicated that a grading mechanism was designed and constructed in which the sizing plates are linked to the roller chain and the other side slides against the guide plate. The opening between sizing plates is gradually increased as the roller chain moves. Fruits enter the grading mechanism and lie on the gaps between sizing plates, dropping through the openings and into bins when the openings become large enough. Sorting efficiency and sorting purity were both 88%, while sorting efficiency and sorting purity decreased to 74 and 76%, respectively, when 3 grades of plum fruits were sorted.

Genidy (2003) stated that the machine grading capacity increased by 22.2 % when the cylinder speed of feeding cells was increased from 10 – 40 rpm (0.11- 0.42 m/s) at different levels of tilt angles during grading the muskmelon.

Jaren and Garcia-Pardo (2002) concluded that there is no clear definition of fruit quality. Many quality factors such as size, shape, color, flavor, firmness and taste are related to ripeness. Since many quality factors of agricultural products are related to their physical properties, it is necessary to develop non-destructive techniques to evaluate post-harvest ripeness based on these physical properties.

Tabatabaeefar and Rajabipour (2005) concluded that for agricultural materials, volume, mass and projected areas are the most important ones in sizing systems. They reported that to design a machine for handling, cleaning, conveying, and storing, the physical, mechanical and hydraulic properties of agricultural products must be known.

Mazidi, *et al*. (2016) stated that the mechanical damage during packaging can be determined by study of firmness changes of fruit.

Okra pods are usually graded to standard sizes < 1.5, 1.5 to 3.0, 3.0 to 4.5, > 4.5 cm. Trade Manager (2017) showed that general description of frozen okra length are super 0.0 to 3 cm, one 3 to 6 cm two 6 to 9 cm. Okra pods are the most complicated and difficult to prepare before process. However, Owolarafe and Shotonde (2004) reported that the average of an okra pod are 54.6, 28.6 and 26.7 mm for length, width and thickness, respectively. The process of okra pods involves slicing, drying and grinding.

Many types of machines are available to do this work; most of them are complex and expensive since they incorporate devices to facilitate sorting for quality, accurate sizing mechanisms and devices to facilitate packing. The cheapness and simplicity of grading machines would encourage their use on national scale.

The main objective of this study is to develop, construct and test a prototype a simple machine for okra fruits grading, to evaluate the performance of the proposed machine and recommend the required improvements based on the results.

MATERIALS AND METHODS

1- Materials:-

The experiments were carried out using the Egyptian okra crop variety (Baladi). This variety was obtained from Horticultural Research Institute, (A.R.C.) Giza, Egypt. This variety was selected based on its recent coverage area and the expected future expansion according to Ministry of Agriculture yearly bulletins.

2-The developed machine:-

The proposed grading machine Figs. (1- A) and (1-B) used in this study, was constructed, developed and tested at the workshop of Ag. Eng. Res. Inst. (ARC).

Fig. 1-A. Actual photo of a proposed simple grading machine

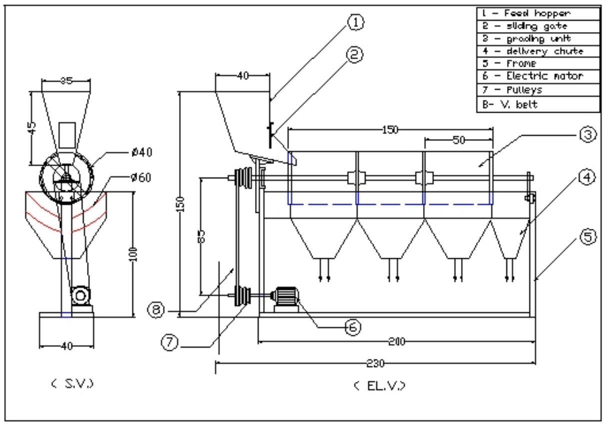

Fig. 1-B. Side view and elevation view of a simple grading machine

As shown in Fig. (1- A and B), the cylindrical reel-separator consists of frame constructed from steel hollow square bar (4 × 4 cm) 0.5 cm thick welded together. The frame dimensions (length, width and height) were 200, 40 and 110 cm, respectively.

The hopper of machine was manufactured to feed the fruit into the reel-separator with the dimensions of 35x40x45 cm for length, width and height, respectively. It was made of iron sheet of 1 mm thickness. The sides of this hopper had a gradual slope to allow sliding of fruits.

Based on the physical properties of okra fruits under this study, and according to the quality standard for exported canned and frozen foods (Ministry of Economy and Foreign Trade, 1992), okra fruits are sized into four different categories (Specifications of Freezing Okra) as follows:

Size (1) < 15 mm in length ranked: Okra Zero
Size (2) 15 - 30 mm in length ranked: Okra One
Size (3) 30 - 45mm in length ranked: Okra Two
Size (4) > 45 mm in length ranked: Okra Super.

Canned okra are sized into three categories as follows:

Category (1) < 3.0 cm in length ranked: Small.
Category (2) < 4.0 cm in length ranked: Medium.
Category (3) < 5.0 cm in length ranked: Large.

The maximum mixing permitted percentage between any two sizes of pods must be less than 5 percentage.

Two different grading units (sieves) were made. The first unit of parallel bars, while the other has square cells Fig. (1- C).

Each grading unit consists of three parts (A, B and C); each part of 40 cm diameter and 50 cm length. The sieves are arranged in sequence (one after the other) according to the size, starting from the small mesh (15 mm), medium mesh (30 mm), a ending with large mesh (45 mm). The sieves are mounted on the machine frame using electrical motor with 0.75 kW and the slope of the sieve needed to get the proper flow by means of bolts and adjustable holes.

The grading unit is set on two rotating rollers each one is supported by two adjustable ball bearings with grease gun, which are attached on the main frame by means of bolts. The grading unit slightly tilted downwards in the direction of crop travel to encourage the fruits to pass along the grading unit.

The working process of a cylindrical sieve is given below. The fruit mix is delivered from one end of the rotating cylindrical sieve (inclined or horizontal). Then the fruits try to reach the other end of the cylinder.

During this action, particles located at the lower portion of the cylinder are lifted upward by the screen surface to some height after which they are again lifted along with it and slide down. They gradually move toward the opposite end of the cylinder. The particles are in contact with only a part of the cylindrical surface and have no relative velocity with respect to it during their lift for these reasons and because sieving of small particles is possible only when they have some finite relative velocity.

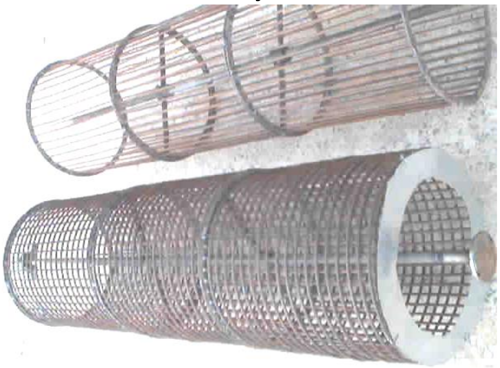

Fig. 1-C. Actual photo for two grading unites.

3-Theoretical considerations of the cylindrical Sieves:

The nature of the motion of fruits over the surface of a cylindrical sieve depends upon the coefficient of friction on the given surface; the kinematics operating condition is governed by centripetal acceleration rω 2, the initial conditions of motion of the particles, the point at which they are delivered on to the sieving surface and their initial velocity.

Depending upon the relationship among the above factors, the fruit in the cylinder may slide along it, separate from its surface and perform a free flight or may move with the surface being at rest relative to it. In the last case the fruit material is not sieved (Bosoi *et al*. 1991).

The release of fruits (particles) in a cylindrical sieve depends upon their relative velocity and the forces acting on them. These forces are:

- The weight of the particle *mg*, directed downward.
- The centrifugal force $m\,r\,\omega^2$

Where:

- **(m) is the mass of the particle;**
- **(r) is the radius of the cylinder;**
- **(ω) is the particle angular velocity (at critical speed the angular Velocity of particle $\omega_p = \omega$).**

The motion of the particle on the cylinder surface is not determined by the tangential forces alone. But, if the resultant of the normal forces (F_n) is not directed towards the cylinder surface, the particle will loose contact with the cylinder.

To find the equations that describes the motion of the particle at a critical speed of the cylindrical sieve Fig. (2), it can be found that:

$F_n = m\,r\,\omega^2 - mg \sin á$ …. (1) **in the normal direction**

$mg \cos á = \mu\, Fn$ ……… (2) **in the tangential direction**

Where:

- **$(á)$ is the angular position of particle on the sieve surface measured from the horizontal axis in the direction of rotation;**
- **(μ) is the coefficient of friction between the particle and cylindrical surface.**

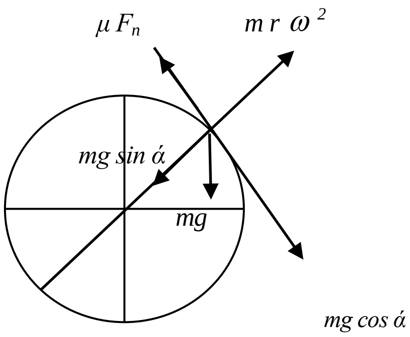

Fig. 2. Forces acting on a particle of fruit in a rotating cylinder

By substituting (F_n) from equation (1) into equation (2) then:

$$mg \cos á = \mu\,(m\,r\,\omega^2 - mg \sin á) \quad \text{…..(3)}$$

$$g \cos á = \mu\, r\,\omega^2 - \mu\, g \sin á$$

$$\mu\, r\,\omega^2 = g \cos á + \mu\, g \sin á$$

$$\omega^2 = \frac{g\cos\alpha' + \mu g \sin\alpha'}{\mu r} \quad \text{……………. (4)}$$

$$\omega = \sqrt{\frac{g}{\mu r}\left(\cos\alpha' + \mu \sin\alpha'\right)} \quad \text{…………..…. (5)}$$

But

$$\omega = \frac{2\pi N}{60} \quad \text{…………………………….………(6)}$$

From equation (5) and equation (6) we get:

$$N = \frac{60}{2\pi}\sqrt{\frac{g}{\mu r}\left(\cos\alpha' + \mu \sin\alpha'\right)} \quad \text{…………..…. (7)}$$

At $á = 90^\circ$

$$N = \frac{60}{2\pi}\sqrt{\frac{g}{r}} \quad \text{………….………...… (8)}$$

The previous equation (8) shows the number of rotations per minute (critical speed). Under this study, and by substituting in equation (8) the number of rotation per minute *(N)* for sieve should be lower than 66.8 rpm.

The sieves are set inclined to the horizontal plane, to improve the internal pressure forces during the rotation of the particles mass. According to Klenin *et al*. (1985) the angle of sieve inclination (θ) was selected from the condition θ ≤ ϕ. Where (ϕ) is the friction angle between the fruits and the sieve surface.

In this study, the slope angle of the cylindrical sieves on the horizontal plane was selected experimentally as (9°).

4- The studying factors:

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

1. Four different fruits feeding rates (350, 400, 450 and 500 kg/h);
2. Four different speeds for grading unit 20, 35, 50 and 65 rpm, (0.419, 0.733, 1.047 and 1.361 m/s).
3. Two types of wire mesh cell shape (parallel bars cells and square cell).

The number of rotations per minute *(N)* and the slope angle of cylindrical sieves (θ) on the horizontal plane were considered according to the theoretical consideration as described above.

5- Calibration of the feeding mechanism:

The following steps were carried out to calibrate the feeding mechanism to give the required feed rates of okra fruits.

- The hopper was filled with pods.
- The gate opening was adjusted to control the output of the fruits.
- The machine was run for two minutes for each test. This period was measured from the instant of full dropping the fruits through the hopper opening.
- The discharged fruits were collected in plastic bags to determine the feeding rate of okra fruits (kg/h).

6-Test Procedure:-

- Before carrying out the tests, the samples are manually cleaned to remove impurities and the unwanted materials.
- The machine is paid on the ground. The fruits were put into baskets and manually discharged into the feeding hopper.
- The fruits were dropout from the feeding unit to the grading unit either square or longitudinal cells to be graded pods into 4 sizes. Then discharged fruits are collected from different baskets.
- During grading process, the consumed time of operation from the moment of fruits dropping until finishing time is measured, the graded okra pods are weighted and recorded. Then, machine grading efficiency (%), machine productivity (kg/h), and okra pods mechanical damage (%) are calculated for each test.

7- Measurements:-

7-a) Fruit physical and mechanical characteristics

- Fruit principal dimensions:

To decide the size of the machine's hopper and cells of cylindrical sieves, the measurements of fruit length, diam, mass, sphericity, shape and friction angle were taken as shown in Table (1).

Table 1. Physical and mechanical properties of okra pods

property	Range		Average
	Min.	Max.	(Mean)
Moisture content %(wet basis)	11.81 -	13.40	12.42
length, mm /100	13.10 –	60.11	34.40
diam., mm /100	10.50 –	22.30	15.63
mass ,g /10	0.96 -	10.37	4.24
Sphericity , %	52.53 -	85.62	64.00
Shape,	Conical ribbed		
friction angle on galvanized steel sheet , degree.	19.7		

7-b) Machine grading capacity and efficiency:

The grading capacity for the developed machine was determined according following formula:

Machine capacity (Mp) = M_w / t , (kg/h) …… (9)

Where:

M_w = Mass of classified fruits from the whole unit in kg;
t = The time consumed in operation, h.

The total grading efficiency of the machine was estimated according to Klenin *et al.*, (1985) using the following formula:

Machine grading efficiency (η) = $(m_1 + m_2 + m_3 + m_4) / m$, (%) …(10)

Where:

m= Total mass of fruits, kg;
$m_1 + m_2 + m_3 + m_4$ = Averaged mass of different sizes, kg.

7-c) Mechanical damaged percentage:

Mechanical damage percentage for okra pods due to grading was measured as follows.

Okra's bruises were evaluated, immediately as visible damage, which can be seen by bare eye. Scuffed fruits (with surface abrasion damage to skin) and those with flesh damage were separated from each fraction and there percentages based on the weights of the corresponding fractions were taken as okra pods mechanical damage. Then the mechanical damage of fruits was classified according to (Kader, 1992) into the following categories:

Bruising score	% of fruit area affected	
1- No symptoms	Zero	
2- Slight	< 2 %	
3- Moderate	2 – 5 %	
4- Severe	5 – 10%	Unmarketable
5- Extreme	> 10%	

RESULTS AND DISCUSSION

1- Machine grading capacity:

Fig. (3) illustrates the effect of different speeds of cylindrical sieve (rpm) and different sieves feeding rates (kg/h) using two types of cell shape (parallel bars and square cells) on the machine grading capacity during the grading process of okra pods .

It can be seen from Fig. (3) that increasing sieve speed during grading process of okra pods using parallel bars and square mesh from 20 to 65 rpm at any fruit-feeding rate in the range of 350 to 500 kg/h cause a corresponding increase in machine grading capacity.

Similarly, it can be observed that increasing sieve rotating speed during the grading process of okra fruits using parallel bars mesh causes higher machine grading capacity compared with square cells. This increase in machine grading capacity by using parallel bars mesh may be due to the less probability of sieves clogging compared with the square mesh.

In addition, it can be seen that increasing sieve-rotating speed from 20 to 65 rpm at all fruits feeding rates from 350 to 500 kg/h causes a higher increase in machine grading capacity.

The low capacity values were 281.3 and 273.4 kg/h for parallel bars cells and for square cells, were obtained during grading okra fruits at 350 kg/h fruit feeding rate and 20 rpm sieve rotating speed. The higher values were 447and 436 kg/h, for okra fruits at 500 kg/h fruits feeding rates and 65 rpm sieves speed using parallel bars and square cells, respectively.

2- Machine grading efficiency

Data tabulated in Fig (4) show the effect of grading parameters and their interactions on the machine grading efficiency.

It can be seen from Fig. (4) that increasing the speed of sieves from 20 to 35 rpm at any fruit feeding rate in the range of 350 to 400 kg/h with parallel bars and square cells cause a positive increase in the machine grading efficiency for okra fruits comparing with square cells. This increase in the machine grading efficiency was followed by a decrease in grading efficiency as the sieve rotating speed increased from 35 to 65 rpm. Whereas, increasing the speed of sieves from 20 to 50 rpm at any fruit feeding rate in the range of 450 to 500 kg/h using square cells cause a corresponding increase in the machine grading efficiency. This increase was followed by a decrease in machine grading efficiency as the sieve rotating speed increased from 50 to 65 rpm. This decrease in machine grading efficiency by increasing rotating speeds of sieves may be due to the increase in the fruits movement that made the fruit bounce on the sieve and this in turn decreases the fruit separation.

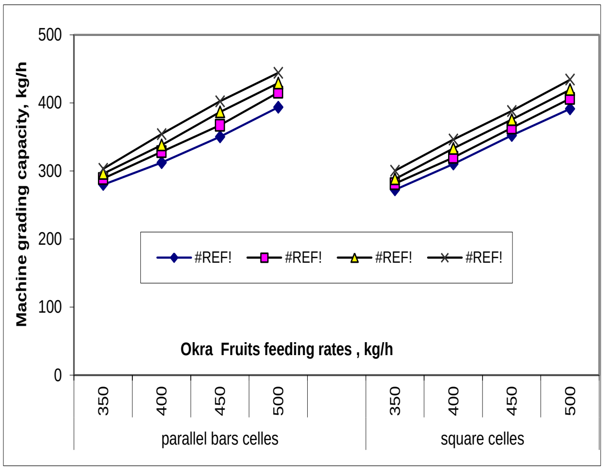

Fig. 3. Machine grading capacity as affected by different sieve rotating speeds, different fruits feeding rates for both types of sieve cells using okra fruits.

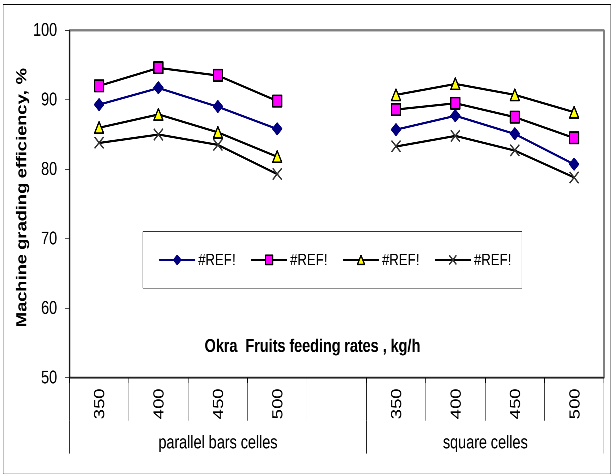

Fig. 4. Machine grading efficiency as affected by different sieve rotating speeds, different fruits feeding rates for both types of sieve cells using okra fruits.

The same trend of increase in the machine grading efficiency due to increasing fruits feeding rates from 350 to 400 kg/h was also noticed at all sieve speeds in the range of 20 to 35 rpm and at mesh types (parallel bars and square shapes).

This increase was followed by a decrease in machine grading efficiency as the fruits feeding rates increased from 450 to 500 kg/h. This may be attributed to the fact that at higher fruit feeding rates, the amount of fruits conveyed to the grading unit reached to high value and this caused a rick of fruits on this unit, thus some fruits passes without grading.

This decrease in grading efficiency by increasing feeding rates from 450 to 500 kg/h may be due to the increase in the fruit movement giving it more ability to jump on the sieve and this in turn increased the ratio of fruit mixing. These results were in line with Bosoi *et al*., (1991) and El- Sayed (2004).

Under the same conditions, it can also be seen that parallel bars cell shape caused an improvement in grading efficiency compared with square cell shape. The reason of depression of grading efficiency with square cell shape may be due to the increase in clogging of sieves openings compared with parallel bars cell.

It should be mentioned that the data of grading process at feeding rates 450 and 500 kg/h should be excluded from the efficiency calculation since it was found that grading efficiency decrease at these levels of feeding rates as shown in Fig (4).

3-Mechanical damage percentage:

Mechanical damage percentage was measured during okra pods grading under optimum operation condition {35 rpm (0.733 m/s) cylinder speed and 400 kg/h feeding rates, using parallel bars cell shape. And 50 rpm (1.047 m/s) cylinder speed when using square cells at the same feeding rate of okra fruits},

It can be seen from Table (2) that the mechanical damaged percentage of okra fruits increased when grading process was carried by square cells compared by parallel bars cells. The values of mechanical damage percentage were lower than the maximum defects permitted for marketable okra fruits, so it should be excluded.

Table 2. Okra's mechanical damaged at optimum grading conditions.

Cell type	Maximum defects permitted for marketable okra fruits, %.	Mech. Damage, %	Grading Effie, %
Longitudinal bars	5.0	2.39	95.2
Squares		3.81	92.6

In other words, grading okra fruits by the proposed machine at optimum grading conditions, produced okra pods defects (mechanical damaged) lower than the limits permitted for marketable okra's yield as described in the mechanical damage classification (Kader, 1992).

Increasing the percentage of mechanical damage using the square cells shape may be attributed to increase the impact time for fruits with cell sides during the grading process, and that led to increase the mechanical damage.

So, one can say that, it is quite safe to use the developed separator from the damage point of view at the optimum parameters causing the higher grading efficiency and capacity.

CONCLUSION

The optimum operating parameters for the modified grading machine by using the parallel bars cells were 400 kg/h for fruit feeding and 35 rpm for sieves rotating speed. At the same feeding rate (400 kg/h) and by using square cells the rotating speed of the sieves should be 50 rpm

The mechanical damage increased when grading process was carried out by square cells compared with parallel bars cells. Grading okra pods by the developed machine at optimum grading conditions, produced okra with lower defects than the limits permitted for marketable okra's.

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تطوير وتقييم الة صغيرة لتدريج قرون البامية

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تعتبر ثمار البامية الطزجة او المجففة اوالمجمدة واحدة من ثمار الخضر المفضلة في مصر والدول العربية والكثير من الدول الأخري لما لها من مذاق مميز و قيمة غذائية عالية حيث تحتوي علي البروتين والحديد والعديد من الفيتامينات مثل أ، ب مركب ،ج .وهي مصدر غني بالألياف التي تقي الانسان من كثير من الأمراض وخاصة سرطان القولون . ولما كان تدريج محاصيل الخضر والفاكهة من العمليات الضرورية لزيادة تسويقها وكذا تحديد سعر المنتج في الاسواق سواء المحلية او التصدير مما يعني زيادة الدخل والعملة الصعبة. و يهدف البحث الي تطوير وتصنيع وتقييم ماكينة صغيرة محلية الصنع لتقوم بتدريج ثمار البامية. بهدف نشرها داخل القرى المصرية كآلة بسيطة يمكن نقلها بين الحقول مما يساعد على تقليل نسبة الفاقد والتالف من الثمار خلال مراحل التداول المختلفة وتوفير العملات الصعبة التي تنفق في استيراد هذه الآلات وتشجيع التصنيع المحلى لهذه النوعية من الآلات بخامات مصرية متوفرة بالسوق المحلى. تم إجراء التجارب العملية خدام الآلة المصنعة لدراسة تأثير بعض العوامل الهندسية مثل معدل تغذية الثمار(350، 400، 450، 500 كج/س)، سرعة دوران الغرابيل 20، 35، 50، 65 لفة/ د (0.419 ، 0.733، 1.047و 1.361 م/ث)، شكل خلايا الغرابيل (قضبان متوازية، خلايا مربعة) والتي تؤثر بدورها على سعة وكفاءة وأداء الآلة المقترحة. ويمكن تلخيص أهم نتائج هذه الدراسة في النقاط التالية: -العوامل المثلي لتشغيل الآلة باستخدام الخلايا ذات القضبان المتوازية كانت عند سرعة 35 لفة/دقيقة (0.733 م/ث) ومعدل تغذية للثمار قدره 400 كج/س حيث أعطت أعلى كفاءة تدريج (95.2 %) والتي توافقت مع سعة للآلة قدرها(331 كج/س). بينما كانت العوامل المثلي لتشغيل الآلة باستخدام نفس معدل التغذية للثمار مع الخلايا المربعة وسرعة 50 لفة/دقيقة (1.047 م/ث) لغرابيل التدريج حيث كانت أعلى كفاءة تدريج (92.6 %) والتي توافقت مع سعة للآلة قدرها(335 كج/س). -انخفضت نسب التلف الميكانيكي لثمار البامية عند تدريجها باستخدام الخلايا ذات القضبان المتوازية عند مقارنتها بالخلايا المربعة الشكل وذلك تحت ظروف التشغيل المثلي للآلة، وكانت نسب التلف الميكانيكي للثمار منخفضة عن النسبة المسموح بها دوليا (5 %).