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Development of Grading Machine for Citrus Fruits (Valencia Orange)

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ABSTRACT

This research aims to develop and fabricate an innovative and simple prototype of a grading machine for citrus fruits. Design feature includes three major characteristics are a simple design and ease of use, its parts are locally available materials and ease of construction in addition to possibility sizing most of spherical fruits by changing some adjustments. The machine was adjusted to the grading of Valencia orange fruits into five categories. The results revealed that the suggested design achieved high sizing efficiency by using the machine at an angle of inclination of the tilted flat (A_f) that corresponds to the coefficient of static friction of fruit types graded. Also, the roller of the grading system must rotate against the fall of the fruit in order not to get stuck between the roller and the tilted flat. But, it was clear that no effect for speeds of the revolving roller on the machine performance. Percentages of the machine efficiency were 78.2, 94, and 77.8 % at values of the angle (A_f) 16º, 20º and 24º respectively using the speed of the revolving roller (ω_r = 10 rpm). Also, the results indicated that the machine throughput capacity did not change significantly by increasing the speed of the revolving roller at any given angle. The maximum values the machine throughput capacity were 105, 136.8, and 152 kg/h. at values of the angle (A_f) 16º, 20º and 24º respectively using the speed of the revolving roller (ω_r = 10 rpm).

Keywords: sizing machine, citrus fruits, sorting by size, spherical fruit, valencia orange.

INTRODUCTION

Citrus fruits are the major horticultural crops in Egypt because of its nutritional, consumption, processing, export value and high content of vitamin C. The cultivated area of citrus (Orange fruits) is 306.9 thousand feddans (128.898 thousand hectares) in 2016/2017. The total annual production of citrus (Orange fruits) in Egypt is about 3.2 million tons in 2016/2017. According to the Central Agency for Public Mobilization and Statistics (CAPMAS) Annual Bulletin of Crops and Plant Production Statistics 2016/2017. In fact, post-harvest processes for fruits and vegetables affect directly quality and market value, especially fruit crops. Post-harvest process for fruits generally, included washing, sorting by size, grading, packing, transporting and storage. Sorting and grading of fruits will increase its quality which is beneficial both to the consumer and the producer. Therefore, any systems which perform these processes will be of great value. Dragan *et al.* (2014) reported that after harvest, fruit crops differ in many properties. Fruit sorting performed after harvest is a set of technological operations, whose aim is to sort crops for placement on the market, preservation or consumption as fresh fruit, or industrial processing. In order to put fruit crops on the market, they must be of uniform quality and size. The process of sorting by size may play an important role to ensure the high quality of fresh fruits and maturity. Fruit sizing has value in assessing crop health and yield estimation Zhenglin *et al.* (2018). The basis of fruit gradation is external factors including size, shape, color, defect and external damage, etc. However, consumer choice is always to have fruits with equal size. In fact, this is the basis of the sorting of fruits based on their size. Proper sorting of fruit ensures uniformity in fruit size, reduces packaging and transportation costs and also provides an optimum packaging configuration. Thus, in the packaging industry, grading of fruits based on size is one of the important tasks that are performed. Though human graders can do this task, machine vision has proved to be a great tool that can replace human sorters for consistent and reliable judgment in estimating and comparing the size of the fruits. Human graders may make different judgments on the same product at different instances and also if done by human graders it will be time-consuming also Ajay and Amar (2014). Areej *et al.* (2015) reported that color and size are the most important features for accurate classification and sorting of citrus. Because of the ever-growing need to supply high-quality fruits and vegetable products within a short time, automated grading of agricultural products is getting special priority among many farmer associations. Manual sorting is based on a traditional visual quality inspection performed by human operators, which is tedious, time-consuming, slow and non-consistent. It has become increasingly difficult to hire personnel who are adequately trained and willing to undertake the tedious task of inspection. A cost-effective, consistent, superior speed and accurate sorting can be achieved with automated sorting. Iqbal and Gopal (2015) mentioned that over the decades, a lot of advancement has taken place in each of the sorting/grading systems of fruits. Whether it is a mechanical or machine vision-based fruit sorting, mechanical handling subsystems play a major role in the overall performance in terms of throughput and safe handling of fruits. But Iqbal *et al.* (2009) reveals that a few industries abroad are manufacturing and selling a variety of fruit sorting and grading equipment, but all of them are very costly which cannot suit the pockets of small-scale industries existing in developing countries. Eissa and Khalik (2012) indicated manual sorting is based on a traditional visual quality

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inspection performed by human operators, which is tedious, time-consuming, slow and non-consistent. It has become increasingly difficult to hire personnel who are adequately trained and willing to undertake the tedious task of inspection. Nandi *et al*. (2014) said that in the present common scenario, sorting and grading of fruit according to maturity level are performed manually before transportation. This manual sorting by visual inspection is labor-intensive, time-consuming and suffers from the problem of inconsistency and inaccuracy in judgment by different humans. Aniket and Awate (2016) reported that the agriculture sector plays a key role. For the proper price of any agriculture product, grading according to size is necessary. And it is also a value-adding technique to the product. To makes the product more attractive and improve its processing qualities uniformity in size is important. At present, the size grading of most agricultural products including lemon, garlic, onion, tomato, orange, mandarin, and apple is carried out manually by farmers, agents, whole-sellers, retail sellers, and customers also. Most of the farmers market their products without any grading. Persons engaging in post-harvest crop handling such as collectors, whole-sellers, retail sellers, and farmers cannot use highly technical and costly grading techniques. In the market, fruits are available in a variety of sizes. If there is no uniformity in their sizes, the seller can not get a good price. Fruit grading by a human is inefficient, labor-intensive and error-prone. The automated grading system not only time-saving but also minimizes error. There is a need for a universal fruit grading machine that can be used for grading all circular fruits like Amla, lemon, tomato, orange, apple, and vegetables like garlic, onion as per their size for uniformity. It will be better to use one machine instead of separate machines for separate fruits. The machine should be simple to use so it can be operated by any illiterate person also so that farmers can also use it. Gaikwad (2010) mentioned that customer requirements and availability of technology are the key drivers of change in the sizing methodology. Retail customers are expecting the supply of products in commercial volumes, redesigned packaging and are emphasizing the increased accuracy and definition of sizing. In addition to providing the consumer with a uniformly sized product, consistent sizing is also critical to avoid bruising of fruit during storage and transport. Grading of fruits and vegetables permits fetching high prices to growers and improves packaging, handling and causes an overall improvement in the marketing system. The high value fresh agricultural products such as orange must be carefully handled and graded in order to meet customer demands and quality standards of the national and international markets. Manual grading is carried out by trained operators according to the physical quality parameters of fruits and vegetables. Manual grading is costly and time-consuming. It has become increasingly difficult for fruit and vegetable growers to employ enough manual laborers for handling perishable crops such as orange at the proper time. The number and availability of laborers have become completely inadequate during peak seasons. Ahmad et. al. (2011) mentioned that many postharvest handling technologies such as waxing and modified atmosphere packaging can be applied, but uniformity in size, color, and taste is very important in marketing the products. Size and color are the two essential parameters for the citrus fruit quality often used by the consumers in justifying their purchase. This is confirmed by Peleg (1985) were mentioned that consumers prefer fruits with equal weight and uniform shape. Mass grading of fruit can reduce packaging and transportation costs, and also may provide an optimum packaging configuration. Egypt has very successful and lucrative stations for sorting and packing fruits and vegetables for local consumption and export. Manual sorting in the fruits and vegetable industry continues to be the most prevalent method used El-Sheikha et. al. (2012). Problems inherent in this system include high labor costs, worker fatigue, inconsistency, variability, and scarcity of trained labor. The paucity of available labor and increasing employment costs during the peak harvesting seasons have been identified as the important factors driving the demand for automation of the industry Jarimopas and Jaisin (2008). Accordingly, in most Egyptian farms sizing process of citrus fruits is carried out manually by farmers, agents, whole-sellers, retail sellers, and customers also. The sizing process manually is required labor-intensive and time-consuming. As well practically impossible to get uniformly sorted by size for fruits by labors so it is necessary that scientific research should contribute to the development of simple machines for fruits sizing and suitable for small farms. The machine should be cheap, locally manufactured and easy to use by many local producers and vendors. The current research aims to the development of a sizing machine for citrus fruits and test the machine to the sizing of valencia orange as an example of spherical fruits. Taking into consideration during the development of the machine to fit multiple spherical fruits by changing some simple adjustments.

MATERIALS AND METHODS

The prototype of the sizing machine was constructed in the workshop of the collage. of Agric. Eng. Al-Azhar Univ. Assiut. All the experiments were carried out during the period from 1st of May 2019 to 30th of June 2019. All measurements were done using a random sample of 100 Valencia orange fruits. The samples were taken randomly from "Alwalidia" (سوق الوليدية) market and the measurements were taken on the same day.

Design description of the developed sizing machine:

The technical specification of the developed sizing machine and design-idea during the orange fruits sizing test are shown in Fig. (1).

Fig. 1. The developed prototype of graing machine during experiments.

The machine produces five different levels of fruit size. Design feature of the sizing machine includes three major characteristics are a simple design and ease of use, consumes a very small electric capacity (6 Watt) and its parts are locally available materials, low costs manufacture and ease of construction in addition to possibility sizing most of spherical fruits by changing some adjustments without mechanical damage.

Components of the developed prototype of sizing machine:

Fig. (2) shows the main components of the sizin machine; frame, fruit hopper, revolving roller, tilted flat and motor.

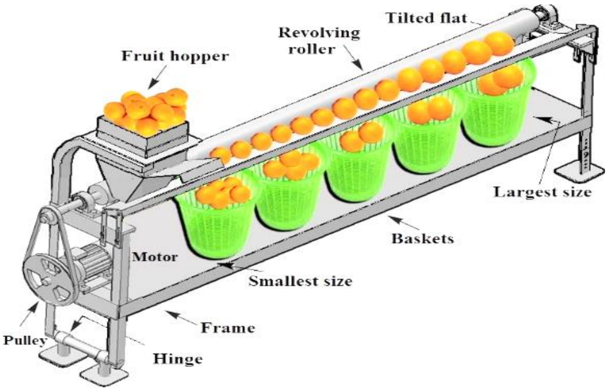

Fig. 2. Detailed description of the developed sizing machine

1- Frame of the machine:

The frame was fabricated from welded iron L-sections 30 × 30 × 3 mm thickness. The frame shape was formed with certain dimensions 500 mm width, 1500 mm length and 900 mm height. Two hinges are assembled at the legs of the frame to control the inclination angle of the machine.

2- Fruit hopper:

The experimental hopper was constructed from galvanized iron sheet. Fruit Hopper dimensions were 380 mm depth, 250 mm width and 300 mm length. Fruit hopper side-slope was fabricated to equal more than maximum friction angle of Valencia orange fruits with galvanized iron sheet surface (Obtained by experiments) (> 16º) = 20º

3- Fruit sizing system:

The grading system consists of a revolving roller and tilted flat. The revolving roller and the tilted flat are the effective parts of the sizing machine. The fruits are graded by controlling the clearance between the revolving roller and the tilted flat as shown in Fig. (3). The clearance must adjust according to a type of fruit and the range of fruit sizes before starting the sizing process. In this paper, the sizing machine was adjusted to the grading of V. orange fruits into five categories. The size of the fruits graded for the five categories that the machine is supposed to give was calculated by assuming that the fruits are 100% spherical as shown in Table (1).

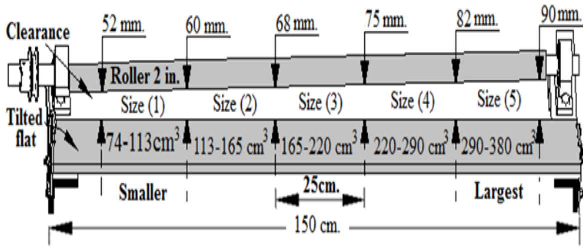

Fig. 3. Adjusting the clearance to sizing the fruits at five categories.

Table 1. The five calculated categories after adjusting the machine.

Set the grading system	Categories				
	Size (1)	Size (2)	Size (3)	Size (4)	Size (5)
The clearance dim., mm.	52 - 60	60 - 68	68 - 75	75 - 82	82 - 90
Size range, cm^3	74-113	113-165	165-220	220-290	290-380
Average fruit sizes, cm^3	95	140	195	260	340

4- Motor:

The engine used in the machine is electric motor (KXTYZ-1 Grill Motor) 6 Watt and given torque 18 kg.cm at 2 rpm. The motor is used only to rotate the roller at a slow speed (10 rpm), in the opposite direction of falling fruit to avoid fruits crowding as a result of friction.

The power requirement was calculated as follow:

Weight of roller with pulleys = 6.5 kg. The load on the roller is 17 fruits. Fruits weight = N. of fruits × Average weight of fruit = 17 × 0.2 = 3.4 kg. Total weight (W) = 6.5 + 3.4 = 9.9 kg. Speed of the roller (ω) = 10 rpm.

Speed of the roller (v) = 0.027 m/s.

μ = Coefficient of friction (unit less) = 0.4

Force = W × μ ……………………………… (1)

So, Force = 9.9 × 9.81 × 0.4 = 39 N

Power required = Force × Speed ……..….…. (2)

Power required = 39 × 0.027 = 1.1 Watt.

Variables of experiments:

The developed prototype of the sizing machine was tested considering the possible variables related to prototype performance to realize the purpose of this research. Variables of experiments as following:

1. **Speeds of the revolving roller (ω_r):**

Three different speeds of the revolving roller 2, 6 and 10 rpm.

2. **The angle of inclination of the tilted flat (A_f):**

The grading machine was fabricated in an innovative way to fit the most spherical fruit shape through the possibility of controlling the angle of the tilted flat. Tests were carried out under three values of the angle 16º, 20º and 24º.

Measurements:

I. Physical and mechanical properties of Valencia orange fruits:

- **Axial dimensions and average diameter:**

A digital Vernier-caliper with an accuracy of 0.01 mm was used to measure the three axial dimensions (Length L, Width W, Thickness T) of randomly selected 100 Valencia orange fruits. The arithmetic mean diameter (Da, mm) was calculated by using the following equation according to, Mohsenin, (1986).

$$D_a = \frac{L + W + T}{3} \dots\dots\dots\dots\dots (3)$$

- **Sphericity ratio:**

Sphericity (∅, %) of fruits was calculated by using the values of the three axial dimensions according to the following equation, Mohsenin, (1986).

$$\emptyset = \frac{(L \times W \times T)^{\frac{1}{3}}}{L} \times 100 \dots\dots\dots\dots\dots (4)$$

- **Mass:**

The mass of individual fruit M, (100 of Valencia orange fruits selected randomly) was determined using the digital electrical balance with an accuracy of 0.001 g.

- **Volume:**

The true volume (V_t) of the individual fruit was measured by the liquid displacement method using toluene (C_7H_8).

- **Projected area:**

Projected area of Valencia orange fruit obtained from a camera mobile phone 24 megapixel. Captured images from a camera were transmitted to a computer. The images of fruits were exported to AutoCAD 2012 program to calculate the projected area (A_P, (mm^2)) of orange fruits.

- **Coefficient of static friction:**

The coefficient of static friction for fruits was measured against two structural materials, rubber and galvanized iron sheet. The board on which the material was fixed, was tilted slowly and gradually until the fruits overcomes the static friction and begin to slide downwards. The angle of inclination was read from a graduated scale and the coefficient of friction was taken as the tangent of this angle. This experiment was repeated ten times and the coefficient of static friction for each replicate was calculated using the following equation according to, *Mohsenin, (1986).*

$$\mu = \tan \alpha \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where: **μ = The coefficient of static friction and α = the angle of friction, degree.**

II. Performance of the sizing machine:

- **Machine grading efficiency:**

The working idea of the developed prototype of the sizing machine is based on falling fruits through the clearance between the revolving roller and tilted flat. Consequently, the fruits can fall through any of the three axial dimensions (Length or Width or Thickness of fruit). The total sizing efficiency of the machine (η) was estimated by comparison with manual sizing, where manual grading is 100% efficient. And then the effect of both speeds of the revolving roller (ω_r) and the angle of inclination of the tilted flat (A_f) on the sizing machine efficiency was studied.

- **Machine throughput capacity:**

Machine throughput capacity (Q, kg/hr) was estimated by using the following equation according to, *Peleg, (1985).*

$$Q = \frac{W_t}{t} \ldots\ldots\ldots\ldots\ldots (5)$$

Where: **Wt = Total weight of fruit (kg) and t = Grading time (hr).**

RESULTS AND DISCUSSION

I. Physical and mechanical properties of Valencia orange fruits:

A summary of the results obtained for the physical and mechanical properties of fruits are shown in Table (2).

Table 2. Physical and mechanical properties of Valencia orange fruits.

Properties		Min.	Max.	Mean	SD	CV %
Axial dimensions, (mm)	L	60	90	74.8	10	13.3
	W	56.7	89.7	71.5	9.3	13.1
	T	53	89.2	70.2	9.2	13
A. diameter, (mm)	Da	56.9	89.6	72.2	9.2	13
Sphericity, (%)	Ø	92.1	99.8	96.5	1.99	2.06
Mass, (g)	M	80	350	190	39.3	20.9
Volume, (cm^3)	V_t	96.5	370.3	207	33.9	16.4
Projected area,	A_p (cm^2)	25.42	63.1	41.6	10.8	25.8
Coefficient of static friction	G. iron	0.24	0.31	0.37	0.05	13.5
	Rubber	0.46	0.69	0.58	0.09	15.5

- **Axial dimensions of Valencia orange fruits:**

From Table (2), the values of length (L) ranged from 60 to 90 mm with a mean value of 74.8 ± 10 mm while the values of width (W) ranged from 56.7 to 89.7 mm with a mean value of 71.5 ± 9.3 mm. It is noted that the values of the thickness (T) are not much different from the values of width where it ranged from 53 to 89.2 mm with a mean value of 70.2 ± 9.2 mm. The arithmetic means diameter (Da) was calculated using the three axial dimensions of fruit, where its value ranged from 56.9 to 89.6 mm with a mean value of 72.2 ± 9.2 mm. There are three possibilities for the fruit to pass through clearance of the fruit sizing system within the developed machine. The fruit falls along its length, width, and thickness.

Fig. (4) shows the distribution of Valencia orange fruits to the five categories when the fruit falls along its length, width, and thickness respectively. This result is an indication of the manual grading of the selected random sample of the fruits. The distribution of the fruits to the five categories (The fruit falls along its length) was 1, 33, 17, 20, and 29 % to size (1), size (2), size (3), size (4), and size (5) respectively. The distribution of the fruits to the five categories (The fruit falls along its width) was 14, 26, 22, 24, and 14 % to size (1), size (2), size (3), size (4), and size (5) respectively. While the distribution of the fruits to the five categories (The fruit falls along its thickness) was 20, 24, 23, 25, and 8 % to size (1), size (2), size (3), size (4), and size (5) respectively.

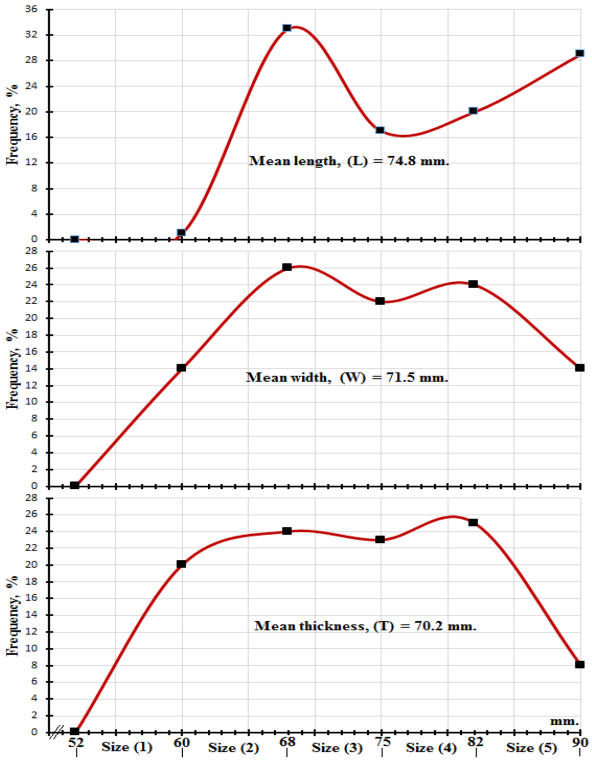

Fig. 4. Distribution of fruits to the five categories when the fruit falls along its length, width, and thickness respectively.

- **Sphericity:**

From Table (2), the value of sphericity ranged from 92.1 to 99.8 % and with a mean value of 96.5 ± 1.99 %. The sphericity was determined to express the shape of Valencia orange fruits.

Buyanov and Voronyuk (1985) reported that if sphericity is less than 0.9, the fruit belongs to the oblate group; if sphericity is greater than 1.1, it belongs to the oblong group. The remaining fruits with intermediate index values are considered to be round. Accordingly, Fig. (5) indicates that the frequent percent (100 %) of Valencia orange fruits in the sample was round (sphericity 90–99.8 %).

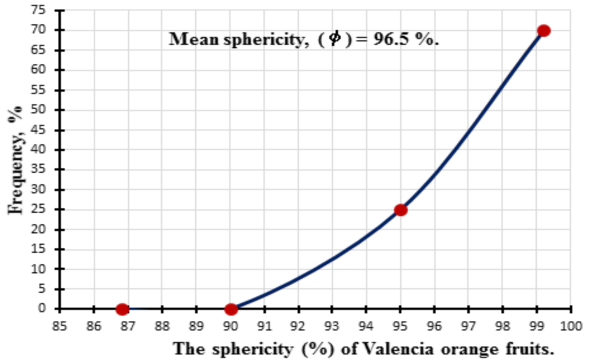

Fig. 5. Frequency distribution curve of the sphericity

- **Mass and the true volume:**

From Table (2), the values of mass and the true volume ranged from 80 to 350 g and from 96.5 to 370.3 cm^3 with mean values of 190 ± 39.3 g and 207 ± 33.9 cm^3 respectively. Fig. (6) shows the relation between mass (g) and the true volume (cm^3) of Valencia orange fruits. This relationship indicates that the correlation between the mass and the true volume is a positive strong correlation (R-squared value = 0.9957) therefore, the resulting equation ($V_t = 0.99\ M + 20.2$) can be used to calculate the true volume of Valencia orange fruits by the mass.

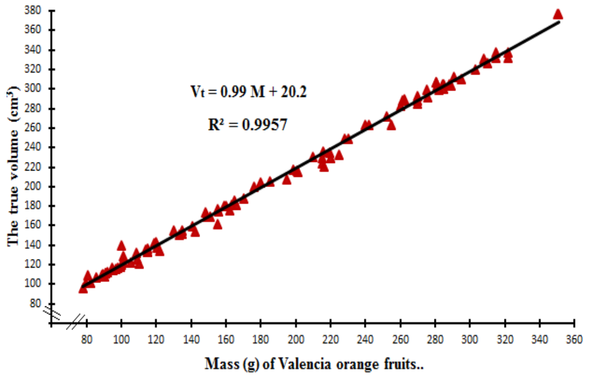

Fig. 6. Relation between mass and volume of fruits

- **Projected area of Valencia orange fruit:**

From Table (2), the value of the projected area ranged from 25.42 to 63.1 cm^2 with a mean value of 40.6 ± 10.8 cm^2.

- **Coefficient of static friction:**

From Table (1), the value of the coefficient of static friction ranged from 0.24 to 0.31 and from 0.46 to 0.69 with a mean value of 0.37 ± 0.05 and 0.58 ± 0.09 on a galvanized iron sheet and on rubber respectively.

II. Performance of the developed sizing machine:

- **Machine sizing efficiency:**

The results of sizing mechanically by the developed machine were then compared to the ones from manually sizing to give an indicator of the machine efficiency. The obtained results of sizing efficiency for the five categories were summarized in Table (3). The machine sizing efficiency ranged from 54.55 to 100 %, from 79 to 100 %, and from 27.3 to 100 % with mean values of 78.24, 94, and 77.76 % under three values of the angle of inclination of the tilted flat (A_f) 16°, 20°, and 24° respectively. It is clear that the percentages of machine efficiency are very different for each category regardless of the variables. This trend may be due to the spherical fruit ratio is not 100 %. Also, these results indicated that the percentage of machine efficiency is 100 % at the size (5) for all cases this trend may be due to that the axial dimensions of fruit fall within the range of clearance dimension for the category (5).

- **Effect of speeds of the revolving roller (ω_r) on the sizing machine efficiency:**

During the preliminary experiments, the roller of the grading system must rotate against the fall of the fruit in order not to get stuck between the roller and the tilted flat. But, it was clear that no effect for speeds of the revolving roller on the machine performance. So, all experiments were conducted at speeds of the revolving roller 10 rpm.

Table 3. Results of the manually and mechanically sizing for Valencia orange fruits and machine efficiency under three various values of the angle (A_f). (D_a, mm. & V_t, cm^2 & η,%)

Sizing process		Property	The five categories														
			Size (1) (52-60 mm) (74-113 cm^3)			Size (2) (60-68 mm) (113-165 cm^3)			Size (3) (68-75 mm) (165-220 cm^3)			Size (4) (75-82 mm) (220-290 cm^3)			Size (5) (82-90 mm) (290-380 cm^3)		
			Min	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min	Max.	Avg.
Manually		N*.		11			28			19			19			23	
		Da	57	60	59	60.3	67.6	63.5	68.6	74.6	71.2	74.9	82	78.5	82.2	89.6	84.6
		V_t	96.5	112.8	107.2	115	162	135	169	217.8	189.5	220.1	289.2	254.1	291.3	377.2	318
Mechanically at three values of (A_f)	16°	N.		6			5 of size (1) + 25			3 of size (2) + 15			4 of size (3) + 13			6 of size (4) + 23	
		Da	57	59.3	58.37	59.2	66.7	62.5	66.5	74.3	69.9	73.2	79.5	80.7	80.4	89.6	84
		V_t	96.5	109.4	104.2	108.7	155.2	128.5	154.3	215.1	179.3	205.5	263.5	246.2	272	377.2	311
		η		54.55			89.3			78.95			68.4			100	
	20°	N.		10			1 of size (1) + 28			19			15			4 of size (4) + 23	
		Da	57	59.7	58.8	60	67.6	63.5	68.6	74.6	71.2	74.9	82	77.63	81.4	89.6	84.2
		V_t	96.5	111.3	106.6	113	162	135	169	217.8	189.5	220.1	289.2	245.6	282.9	377.2	313.2
		η		91			100			100			79			100	
	24°	N.		3			8 of size (1) + 26			2 of size (2) + 17			2 of size (3) + 15			4 of size (4) + 23	
		Da	57	58	57.6	59	66.7	62.3	67.2	74.3	70.4	74.5	81.4	77.2	81.6	89.2	84.4
		V_t	96.5	102	100	107.4	155.2	127.4	159	215.1	183.5	216.3	282.9	241.8	284.6	377.2	313.4
		η		27.3			93			89.5			79			100	

*** N: Number of fruits. - Data were derived from 100 orange samples. - Experiments repeated three times and the averages were calculated.**

- **Effect of the angle of inclination of the tilted flat (A_f) on the sizing machine efficiency:**

From Fig. (7), it is clear that the maximum percentage of machine efficiency was 94 % using the angle of inclination of the tilted flat (A_f) = 20º. This angle corresponded to the coefficient of static friction of Valencia orange fruit on a galvanized iron sheet. So, it is recommended to use the machine at an angle of inclination of the tilted flat (A_f) that corresponds to the coefficient of static friction of fruit types graded.

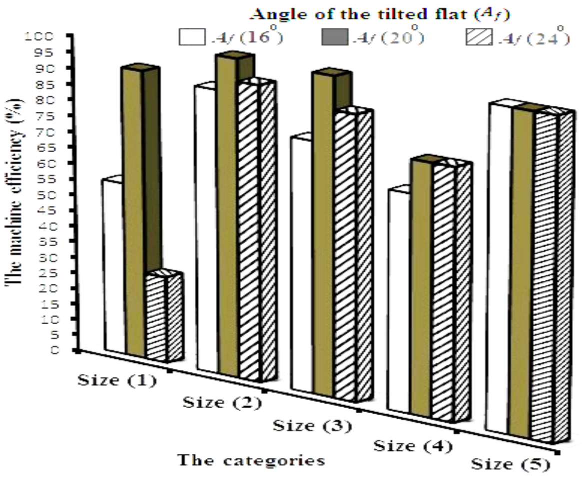

Fig. 7. shows the effect of the angle of inclination of the tilted flat (A_f) on the grading machine efficiency for the five categories.

- **Machine throughput capacity:**

The machine throughput capacity was computed under three values of the angle (A_f) and speed of the revolving roller (ω_r) to observe the effect of these variables on machine throughput capacity as shown in Fig (8).

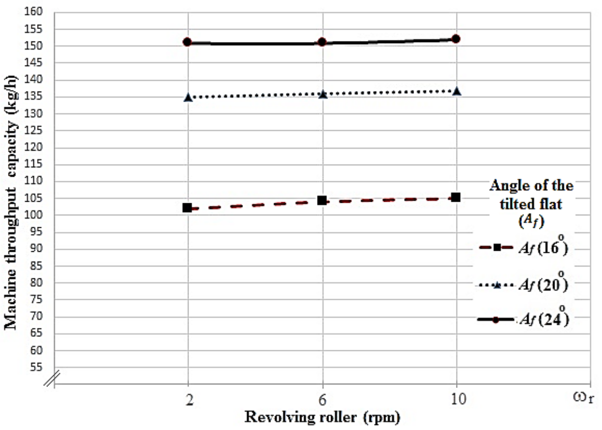

Fig. 8. Effect of the angle (A_f) and speed of the revolving roller (ω_r) on machine throughput capacity.

These results indicated that the machine capacity increased by increasing angle of inclination of the tilted flat (A_f) at any given speed of the revolving roller. This trend may be due to the increased speed of rolling fruits on the tilted flat, but getting the highest sizing efficiency makes it necessary to choose the value of the angle 20º. Generally, these results indicated that the machine throughput capacity did not change significantly by increasing the speed of revolving roller at any given angle. The maximum values the machine throughput capacity were 105, 136.8, and 152 kg/h at values of the angle (A_f) 16º, 20º and 24º respectively using the speed of the revolving roller (ω_r = 10 rpm).

CONCLUSION

Overall results of this research may be concluded as follow:

1. The arithmetic diameter (D_a) of Valencia orange fruits ranged from 56.9 to 89.6 mm with a mean value of 72.2 ± 9.2 mm.
2. The distribution of the fruits to the five categories (The fruit falls along its length) was 1, 33, 17, 20, and 29 % while the distribution of the fruits to the five categories (The fruit falls along its width) was 14, 26, 22, 24, and 14 % as well the distribution of the fruits to the five categories (The fruit falls along its thickness) was 20, 24, 23, 25, and 8 % for size (1), size (2), size (3), size (4), and size (5) respectively.
3. Value of sphericity ranged from 92.1 to 99.8 % with a mean value of 96.5 ± 1.99 %.
4. The values of mass and the true volume ranged from 80 to 350 g and from 96.5 to 370.3 cm^3 with mean values of 190 ± 39.3 g and 207 ± 33.9 cm^3 respectively.
5. The resulting equation (V_t = 0.99 M + 20.2) can be used to calculate the true volume of Valencia orange fruits by the mass.
6. The value of the projected area ranged from 25.42 to 63.1 cm^2 with a mean value of 40.6 ± 10.8 cm^2.
7. The value of the coefficient of static friction ranged from 0.24 to 0.31 and from 0.46 to 0.69 with a mean value of 0.37 ± 0.05 and 0.58 ± 0.09 on a galvanized iron sheet and on rubber respectively.
8. The suggested design of the prototype achieved high sizing efficiency by using the machine at an angle of inclination of the tilted flat (A_f) that corresponds to the coefficient of static friction of fruit types graded.
9. Percentages of the machine efficiency were 78.2, 94, and 77.8 % at values of the angle (A_f) 16º, 20º and 24º respectively using the speed of the revolving roller (ω_r = 10 rpm).
10. The maximum values the machine throughput capacity were 105, 136.8, and 152 kg/h. at values of the angle (A_f) 16º, 20º and 24º respectively using the speed of the revolving roller (ω_r = 10 rpm).

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تطويــر آلة تدريج لثمــار المـوالح (برتقال فالنسـيا الصـيفى)

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تعتبر عملية التصنيف اليدوى للفاكهة حسب الحجم عملية صعبة وكثيفة العمالة، ويهدف هذا البحث إلى تطوير وتصنيع نموذج مبتكر وبسيط لآلة تدريج لثمار الموالح. تم تصنيع الآلة وإجراء التجارب بورشـــة كلية الهندسة الزراعية بجامعة الأزهر بأسيوط، يتميز تصميم الآلة بثلاث خصائص رئيسية هى بساطة التصميم وسهولة الاستخدام، وتستهلك قدرة كهربائية صغيرة جدًا (6 واط)، ومكوناتها الرئيسية عبارة عن خامات متاحة محليًا وذات تكلفة زهيدة، بالإضافة إلى إمكانية تحجيم الفواكه الكروية الشكل وذلك عن طريق ضبط بعض اعدادات الآلة على حسب بعض الخصائص الهندسية للفاكهة. فى هذا البحث تم اختبار الآلة لتدريج ثمار البرتقال الصيفى (فالنسيا) إلى خمس فئات. وقد أظهرت النتائج أن التصميم المقترح للنموذج الأولى للآلة حقق أعلى كفاءة تدريج عند ضبط الماكينة على زاوية ميل للمسطح المائل (A_f) تتقابل مع زاوية الاحتكاك الخارجى للثمار. كما أظهرت النتائج بأنه يجب أن تدور أسطوانة نظام التدريج بإتجاه معاكس لسقوط الثمار حتى لا تنحشر بين الأسطوانة والسطح المائل. كما تبين أيضاً عدم وجود تأثير مباشر وملحوظ لسرعة دوران الأسطوانة على أداء وكفاءة الماكينة. وقد أعطى النموذج المطور للآلة كفاءة تدريج 78.2 ، 94 ، و 77.8 ٪ عندما كانت زاوية الميل (A_f) 16، 20، 24 درجة على التوالى وسرعة دورانية للأسطوانة (ω_r) 10 لفة/الدقيقة. أشارت النتائج أيضا إلى أن سعة الماكينة الإنتاجية لم تتأثر بزيادة سرعة الأسطوانة الدوارة عند أى زاوية ميل. وتبين أن القيم القصوى للسعة الإنتاجية كانت 105، 136.8 و 152 كجم/ساعة عند زاوية الميل (A_f) 16، 20، 24 درجة على التوالى وسرعة دورانية للأسطوانة (ω_r) 10 لفة/الدقيقة.