Development of Affordable Machine for Sizing Egyptian Onion

H.M. Mostafa[1] and A.H. Bahnasawy[2]

[1]Assistant Lecturer
Institute of Agricultural Technology and Biosystem Engineering
vTI, 38116 Braunschweig, Germany.

[2]Assistant Professor
Agric. Eng. Dept., Fac. Agric.,
Moshtohor, Qalubia, P.O. Box, 13736, Benha University, Egypt.

Corresponding author's eMail: harby_sorour@yahoo.com

ABSTRACT

Size grading is an important operation in food processing for the onion export industry in particular. The aim of this work was to develop an appropriate machine for sizing onions, reduce losses and reduce grading costs. Maximum sizing efficiency obtained was 94.9±2.82 % at zero longitudinal angle and at a belt speed of (0.23 m/s), while it was 94.5±3.69% at 10^{o} longitudinal angle for the same belt speed. The overall average of the sizing efficiency (94.33%) was recorded at 20^{o} side angle and the highest grading capacity (1.72 t/h) was obtained at 10^{o} side angle and 10^{o} longitudinal angle. Total costs of grading the produce were 3.89 LE/t. (0.7 US$/t). This machine has the potential to size other crops like potatoes, tomatoes, apples and citrus fruits.

Keywords: onion grading, grading capacity, sizing efficiency, onion bulbs.

1. INTRODUCTION

Onion (*Allium cepa, L.*) is a crop of warm climate and it is grown worldwide. In Egypt, onion is the fourth major exported crop after cotton, rice, and citrus. The total cultivated area was 35,105 ha in 2007 and the total production was 1,375,542 t (CAPMS of A.R.E., 2008).
Manual grading of onion is a labor-consuming and tedious operation coming with many losses. That is why modern technologies, like automatic grading systems, are an utmost need. Sizing is one of the most important operations affecting onion export. It determines the weight of standard sale package, thereby increasing marketing attractiveness, and simplifies the mechanization of different handling systems, such as cutting and peeling. Sizing also has an effect on heat transfer processes, since size-graded produce allows heat transfer uniformity during drying, cooling and freezing processes (Mostafa, 2004).

Grading methods can be divided into subjective (organoleptic) and objective (technical or machine based). According to Ajay et al. (2007), objective grading methods can be divided into: mechanical (measurement of shape, size, volume, weight, density, etc.); physical (heat conductivity, electrical conductivity, etc.); electromagnetic, laser radiation, etc.
The objective of this work was to develop an onion sizing machine capable of working under different operating conditions (variable belt speed and side and longitudinal angles), thus having the ability to size quality onions with reduced bulb losses and costs.

Mosa (1998) designed a diverging bar or roller cylinder sizing machine for orange and Egyptian lime. His results showed that the optimum speed of the feeding conveyor was 0.15 m/s and the most suitable tilt angle ranged from 3^o to 6^o for the cylinder system.

Abdel-Rahman (1999) developed a handling machine for oranges and tomatoes. He analyzed the handling efficiency with respect to parameters such as feeding chain speed (0.15, 0.20, 0.25, 0.30 m/s), sieve speed (150, 200, 300 r/min), sieve slope angle (5, 10, 15 and 20 degrees), and type of cell shape (rectangular and square). He concluded that the optimum operating parameters for the machine were 0.20 m/s for the speed of the fruit feeding chain, 200 r/min for the sieve rocking speed and 15^o of sieve slope angle, for both oranges and tomatoes handling using rectangular cell shape.

Amin (1994) developed a grading machine consisting of a rotating cylinder and perforated concave to grade potato, onion and oranges. The optimum grading performance can be summarized as: the suitable cell area for grading small potato (less than 40 g) was (35-45 mm^2) and for (less than 50 g) was (45-50 mm^2) with drum length of 100 cm, for medium potato sizes (less than 90 g) was (50-75 mm^2) with drum length of 100 cm and big potato tuber was obtained at the outlet end of machine. The grading efficiency for the sizer can be calculated according to the following equation:

$$\eta = \frac{M_1}{M} \times 100$$

where:

η is the sizing efficiency (%);

M_1 is the mass (kg) of the fruits (in correct weight) falling within the size category of all outlets; and

M is the total mass (kg).

Radwan (2000) stated that the total cost of sizing 1t of different varieties of potato, namely Diamant, Spunta and Draga, was 2.44, 2.39 and 2.46 $ respectively, whereas for orange (Navel) it was 1.68 $. Suliman et al. (1998) reported that the cost of materials and manufacturing of the grading machine that they developed was 740.74 $. The running costs (fix + variable) of machine was 1.63 $/h in the case of utilizing the machine for grading citrus fruits (orange and Egyptian lime). The capacity of their grading machine at its optimum speed was 4.2 t/h, which was much higher than the working capacity of an efficient worker (0.1 t/h).

Mahmoudi et al. (2006) designed a separation system, based on combination of acoustic detection and artificial neural networks, for classifying four Iranian's export pistachio nut varieties. System accuracy was of 97.51%, which means that only 2.49% of the pistachio nuts were misclassified.

2. MATERIAL AND METHODS

2.1 Sizer description

The sizing machine consists of the main frame with sliding legs, an onion inlet, a conveyor belt, three outlets and the drive system (Fig.1).

2.1.1 Main frame

The main frame (length = 1.7 m, width = 0.9 m and height = 0.7 m) was made from structural steel angles. The conveyor belt, the sizing unit and the electric motor were mounted onto this frame. The left edge of the frame has two outlets or openings of 30 cm wide each as outlet bearing a vertical sliding gate to control the size grading. The frame has six sliding legs to control the sizer longitudinal and side angles. For example, to increase the side angle it needs to increase the height of right side sliding legs. Similarly, to increase the longitudinal angle the height of the front sliding legs has to be increased.

2.1.2 Conveyor belt

The conveyor belt was made of flat rubber strip. The belt runs over a drive roller and two freely rotating rollers (all of them made from steel, diameter 0.09 m, L = 0.7 m and attached to two changeable bearings) such that each roller is fixed at the lateral side of frame by two ball bearings. The drive roller is connected to the upper pulley. The latter is driven by the lower pulley. One of the freely rotating rollers was fixed at 0.85 m from the drive roller. The other freely rotating roller was fixed at 1.7 m from the drive roller, and it included a mechanism to adjust the belt tension.

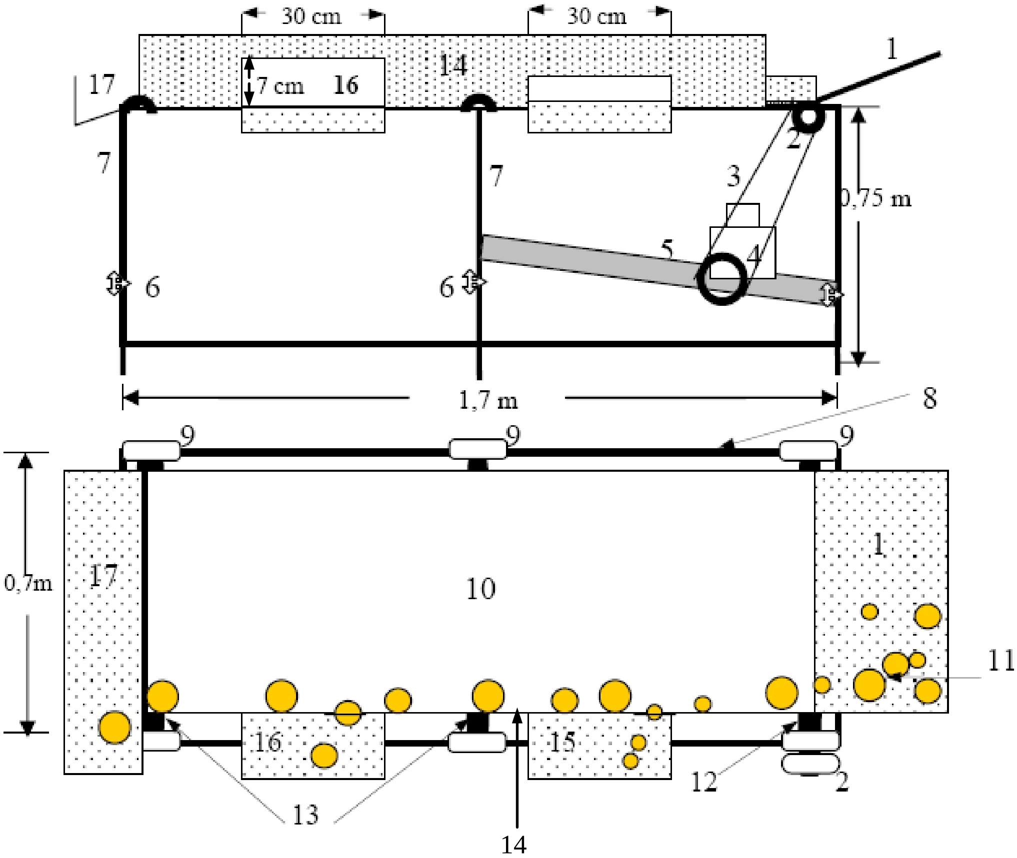

Figure (1): Schematic diagram of the sizer prototype.

1- Onion inlet 2- Upper pulley 3- V-belt 4- Electric motor 5- Base of motor 6- Control pin 7- Sliding legs 8- Main frame 9- Fixed bearing 10- Conveyor belt 11- Onions 12- Drive roller 13- Rotating roller 14-Side Barrier 15- Outlet for the size-group of smallest onions (diameter < 40 mm) 16- Outlet for the medium-sized onions (40 mm < diameter < 70 mm) 17- Outlet for the largest onions (diameter >70 mm)

2.1.3 Grading unit

The grading unit consists of three outlet openings made on the left side of the machine and were used to separate onions into three size categories. The first outlet was rectangular in shape (L = 0.30 m and H = 0.04 m) for the small sized category (< 0.04 m), the second outlet (L = 0.30 m long and H = 0.07 m) for medium size category (from 0.04 to 0.07 m). The third outlet (L = 0.15 m) for large size category (> 0.07 m).

2.2 Grading capacity improvement

Four lanes (1, 2, 3, and 4, Figure 2) were implemented by fixing three partitions with openings on the conveyor belt to increase the grading capacity. These lanes were made similar to those on the sizer prototype before modification (Figure 1). To limit the movement of the onion bulb until close to the grading opening, these openings were adjusted at a distance, which suit the bulb movement on the belt as shown in Figure (2).

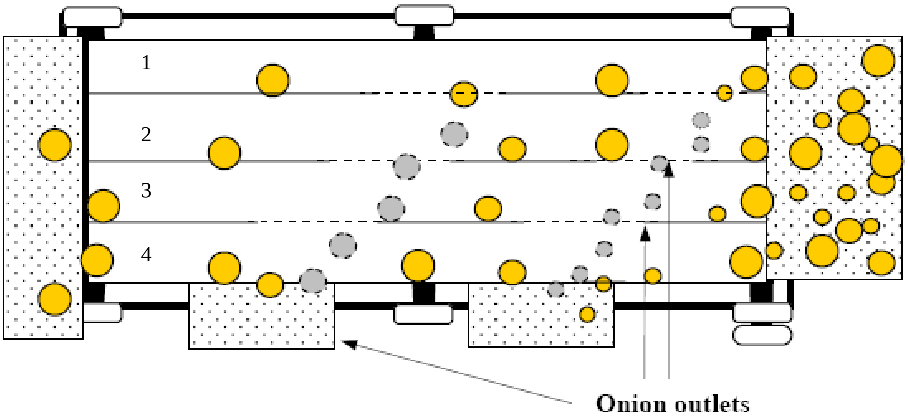

Figure (2): Sizer Prototype after modification

2.3 Power source and its transmission

A 0.35 kW (1400 r/min) electric motor powered the developed grading machine. The motor was connected to a gear box to reduce its speed from 1400 to 17 r/min by combining pulleys of different diameters running over v-shaped belts.

2.4 Grading efficiency

A vernier caliper with a resolution of 0.01 mm was used to measure the linear onion dimensions for each outlet and calculate the ratio of well-classified bulbs to total number of bulbs (well-classified plus misclassified bulbs) for the same outlet. For example, the second outlet corresponds to the second onion category (4-7 cm diameter): if a small bulb (< 4 cm) did not pass though the metering gap of first outlet and passed through the metering gap of the second, this bulb was counted with as a misclassified bulb. The grading efficiency of the outlet was calculated according to the following equation (Mostafa, 2004):

$$\eta_1 = \frac{N_1}{n} \times 100$$

where:

η_1 is the sizing efficiency (%);

N_1 is the number of the well-classified bulbs for an outlet;
n is the total number of bulbs passing through the metering gap of the considered outlet.

The total efficiency of the machine was calculated as the average of the efficiencies of each category using the following equation:

$$\eta_{Total} = \frac{\eta_1 + \eta_2 + \eta_3}{3}$$

where:

η_{Total} is the total grading efficiency of the machine (%),
η_1, η_2, η_3 are the efficiencies of the classified bulbs for first, second, and third outlet respectively.

2.5 Grading capacity

The grading capacity was calculated according to the following equation (Radwan, 2000):

$$C = \frac{M \times 60}{T_G}$$

where:

C is the grading capacity of the machine (kg/ h);
M is the mass of classified bulbs (kg) and
T_G is the grading time (min).

2.6 Power consumption

The power consumed (kW) was estimated by using the “super clamp meter-300 k” to measure the line current strength (I) and the potential difference (V). The following equations were used to calculate the total consumed power and the useful power (Mostafa, 2004).

$$P = \frac{VI \cos\theta}{1000}(kW)$$

where:

I is the current strength (A),
V is the potential difference (V = 220 volts);
$\cos\theta$ is the power factor (0.64) and
P is the power consumed under machine load (kW).

2.7 Cost of mechanical grading

Fixed costs (deprecation, interest on investment, housing, insurance, and taxes) and variable costs (repair and maintenance, electricity, and labor) are the major capital input for most farmers. Grading cost (L.E. and $/h) or (L.E. and $/t) for proposed grading machine was estimated according to Radwan (2000).

2.8 The grading unit test procedure

The unit performance and efficiency were tested by changing the longitudinal and side angles (by using the prototype sliding legs) at different conveyer belt speeds. Longitudinal angles were 0, 10 and 20 degrees and side angles were 10, 20 and 30 degrees. Belt speeds were kept at 0.10, 0.17, 0.23 and 0.30 m/s. The selection of angles and speeds were made according to Abd-Alla (2000), Abdel-Rahman (1999) and Amin (1994).

For each prototype position (changing angles and speeds), the sizer ran for 15 minuets. One operator was used for manual bulb feeding and a plastic package was fixed with each outlet for bulbs collection. After that, the diameter of each bulb was measured with the vernier caliper to calculate the efficiencies, and all the bulbs were weighed to calculate the grading capacity.

3. RESULTS AND DISCUSSION

3.1 Grading Efficiency

Table (1) shows the effect of side angle of the grading table and the belt speed on the grading efficiency at different longitudinal angles (0, 10 and 20^o) of the table while side angles were 10, 20 and 30^o and belt speeds were 0.10, 0.17, 0.23 and 0.30 m/s.

Data reveal that grading efficiency increased with the increase in the side angle for the selected belt speeds and table longitudinal angle. The average grading efficiency obtained ranged from 85.6-93.5% for the side angle change from 10-30^o at zero degree longitudinal angle, while it ranged from 87.3-95% and 87.4-94.6% for 10 and 20^o longitudinal angles, respectively, for the same side angle that changed from 10-30^o.

Table (1): Effect of side angle and belt speed on grading efficiency at different longitudinal angles.

Grading Efficiency						
Belt speed (m/s)	0.10	0.17	0.23	0.30	Mean	SD
Side angle degree	Longitudinal angle = 0 degree					
10	**85.9**	**87.1**	**91.8**	**77.8**	85.6	5.81
20	**89**	**94.6**	**95.7**	**86.8**	91.5	4.30
30	**90.8**	**98**	**97.3**	**87.8**	93.5	4.98
Mean	88.6	93.2	94.9	84.1		
SD	2.47	5.57	2.82	5.50		
	Longitudinal angle = 10 degree					
10	**90.1**	**91.4**	**90.5**	**77.5**	87.3	6.60
20	**92.6**	**94.5**	**95.1**	**88.1**	92.5	3.16
30	**96.8**	**97.5**	**97.8**	**87.9**	95	4.75
Mean	93.1	94.4	94.5	84.5		
SD	3.38	3.05	3.69	6.06		
	Longitudinal angle = 20 degree					
10	**90**	**92.4**	**89.9**	**77.3**	87.4	6.83
20	**96.3**	**96.2**	**96.8**	**82.2**	92.8	7.12
30	**95.7**	**97.2**	**97.1**	**88.4**	94.6	4.18
Mean	94	95.2	94.6	82.6		
SD	3.47	2.53	4.07	5.56		

SD is the standard deviation

Further, in regards to the change in the longitudinal angle, data show that the change of side angle had greater effect on the grading efficiency compared to the longitudinal angle, where the change of longitudinal angle from 0-20^o caused the grading efficiency to increase by 5.4, 2.0, -0.3 and – 1.5 % at 0.10, 0.17, 0.23 and 0.30 m/s, respectively. Contrary to this, the change in the side angle from 10-30^o increased the grading efficiency by 7.9, 7.7, and 7.2% at 0, 10 and 20^o longitudinal angles. Moreover, it can be seen from data that the grading efficiency increased with the increase in the speed which decreases dramatically by increasing the speed up to 0.3 m/s because of rolling most of small and medium onions toward longitudinal slope and go to large category. The minimum grading mean efficiency was 84.1±5.5% at zero degree longitudinal angles for the highest speed (0.30 m/s), while its value was 84.5±6.06% and 82.6±5.56% at 10 and 20^o longitudinal angles respectively for the same belt speed. The maximum grading efficiency was 94.9±2.82% at zero longitudinal angle, at the third speed (0.23 m/s), while it was 94.5±3.69% at 10^o, at the same speed, while it was 95.2± 2.53% at 20^o, at the second speed (0.17 m/s), which means that when the longitudinal angle increases, the speed may be decreased to attain a high efficiency.

3.2 Grading capacity of the machine

The data in Table (2) show that for all side and longitudinal angles of the grading tables, the grading capacity increased with increasing belt speed. The speed increased 3 times as a result while the change in grading capacity was 1.5 times. Further, data reveal that the change in the side angle had no effect on the grading capacity.

Table (2): Effect of side angle and belt speed on capacity of grading unit at different longitudinal angles.

Grading Capacity (t/h)						
Belt speed (m/s)	0.10	0.17	0.23	0.30	Mean	SD
Side angle degree	Longitudinal angle = 0 degree					
10	**0.58**	**0.63**	**0.71**	**0.90**	0.70	0.14
20	**0.52**	**0.63**	**0.83**	**0.91**	0.70	0.17
30	**0.52**	**0.61**	**0.75**	**0.90**	0.69	0.16
Mean	0.54	0.62	0.76	0.90		
SD	0.03	0.01	0.06	0.01		
	Longitudinal angle = 10 degree					
10	**0.62**	**0.64**	**0.75**	**0.91**	0.73	0.13
20	**0.59**	**0.69**	**0.86**	**0.92**	0.76	0.15
30	**0.60**	**0.63**	**0.81**	**0.92**	0.74	0.15
Mean	0.60	0.65	0.80	0.91		
SD	0.01	0.03	0.05	0.01		
	Longitudinal angle = 20 degree					
10	**0.63**	**0.63**	**0.73**	**0.93**	0.73	0.14
20	**0.60**	**0.78**	**0.87**	**0.92**	0.79	0.14
30	**0.60**	**0.79**	**0.87**	**0.95**	0.80	0.15
Mean	0.61	0.73	0.82	0.93		
SD	0.01	0.08	0.08	0.01		

Multi-regression analysis was carried out to obtain an equation describing the relationship between the grading capacity and belt speed at different side angles. The best fit for the data was:

Regression analysis	
Equation	R^2
φ = 0.377+ 1.705V – 0.0015 S	**0.92**

φ: Grading capacity; V: Belt speed; S: Side angle

3.3 Grading Capacity Improvement

To increase the grading capacity, three feeding lanes were fixed on the belt and had the same openings or metering gaps for the grading of desired categories. Our results revealed that 0.23 m/s belt speed gave the best grading efficiency and capacity comparing with 0.2 m/s speed of fruit feeding chain, and 15 degree of sieve slope angle during orange and tomato handling (Matouk et al., 1999**)**. Data [Figure 3] show that the overall average of the highest grading mean efficiency (94.33%) was obtained for 20^o side angle which was higher in value by 7.8 and 0.36% than those mean grading efficiencies obtained for 10 and 30^o side angles, respectively. Adjusting the grading table at 10^o longitudinal angle gave the highest grading mean efficiency (92.13%) which was higher in value by 1.36 and 0.20% than those achieved for zero and 20^o side angles, respectively. From this, it may be concluded that changing the side angle has a greater effect on the grading efficiency compared to the effect of changing of the longitudinal angle at the same belt speed.

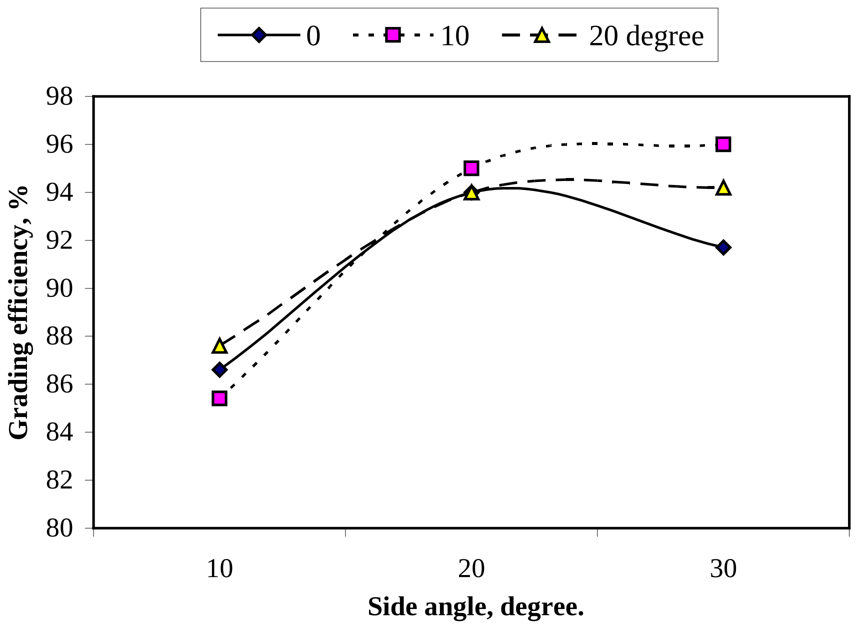

Fig.(3): Effect of side and longitudinal angles on grading efficiency at speed of 0.23 m/s.

Table (3) shows the effect of side and longitudinal angles on the grading capacity at 0.23 m/s belt speed. The highest grading capacity (1.72 t/h) was obtained at 10^o side angle and 10^o longitudinal angle while the lowest grading capacity (1.56 t/h) was achieved at 20^o side angle and zero longitudinal angles. Generally, grading capacity improved at the lower side angle (10^o), which was higher than those of both angles (20 and 30^o).

3.4 Cost Estimation of Onion Grading

The cost of materials and manufacturing of the final designed and developed grading unit was 500 US $. The total costs (Fixed plus variable) are 1.15 $/h. Therefore total costs of grading one ton are 0.7 $ comparing with 2.44 $ for the total cost of grading one ton of potato (Diamant) or citrus fruits with a similar technique according to Suliman et al., 1998, and Radwan, 2000.

Table (3): Effect of side and longitudinal angles on the grading capacity at belt speed of 0.23 m/s.

Grading Capacity, t/h									
Long.angle, degree		**0**			**10**			**20**	
Side angle degree	**B***	**A****	**%*****	**B**	**A**	**%**	**B**	**A**	**%**
10	**0.71**	**1.63**	**229.5**	**0.75**	**1.72**	**229.3**	**0.73**	**1.68**	**230.1**
20	**0.83**	**1.56**	**187.9**	**0.86**	**1.65**	**191.8**	**0.87**	**1.66**	**190.8**
30	**0.75**	**1.58**	**210.6**	**0.81**	**1.58**	**195.1**	**0.87**	**1.60**	**183.9**

* B: before modification, ** A: after modification, ***%: increasing percent

4. CONCLUSION

The results obtained lead us to conclude that the mechanical grading system developed far successfully fulfils its purpose. Onion grading with this technology is a prerequisite for further investigations and for their further improvement. The following recommendations should be considered: The optimum performance of this grading unit was achieved at the conveyor belt speed of 0.23 m/s, the longitudinal and side angles ranged from 10^o to 20^o. The electricity consumption of this unit was very low (0.35 kW·h), so a small generator can be used for operating the machine in the field or in places without a connection to the electricity-grad.

5. FUTURE WORK

Future work, possibilities include adding an optimum feeding system for the machine, which should increase the capacity rate and decreases the cost of grading operation. The design machine could be utilized to grade other crops such as potatoes, tomatoes, apples and citrus. Using the machine with other crops may give better productivity.

6. REFERENCES

Abd-alla, H.E. 2000. A weight grading machine for different fruits and vegetables. Misr J. Agric. Eng. 17 (3):675-696.

Abdel-Rahman, M.M 1999. Handling engineering of some vegetables and fruit crops. Unpublished Ph. D. Thesis, Agric. Mech. Dept., Agric. Fact. Mansoura Univ.

Ajay T., B. Gautam, S. Aseem 2007. Latest Technologies in Cleaning Grading and Handling of all kinds of Seeds, Pulses, Spices, Fruit and Vegetable Produce. International exhibition and conference on processed food, 29 August – 2 September.

Amin, E.A. 1994. Development of grading machine for some Egyptian farm crops. J. Agric. Sci., Mansoura Univ., 19 (7): 2398-2411.

CAPMS. 2008. Annual year book for general statistics. Central Agency for Public Mobilization and Statistics of A.R.E., Egypt.

Mahmoudi A., M. Omid, A. Aghagolzadeh and A.M. Borgayee, 2006. Grading of Iranian's Export Pistachio Nuts Based on Artificial Neural Networks. Int. J. Agri. Biol., Vol. 8, No. 3.

Matouk, A.M.; A.M. EL-Gingy, Y.M. EL-hadidi; E.A. Amin; and M.M. EL-Rahman 1999. Evaluating the effect of some mechanical parameters on handling characteristics of sphere-like crops. Misr J. Agric. Eng., 15(4) 701-719.

Mosa, M.M. 1998. Engineering factors affecting the development of grading machine for citrus. Ph. D. thesis. Agric. Eng. Dept., Agric. Fact. Cairo. Univ.

Mostafa, H.M. 2004. Developing an appropriate system for onion grading. M.Sc. thesis. Agric. Eng. Dept., Agric. Fact. At Moshtohor, Zagazig University\ Benha branch

Radwan, M.S. 2000. A weight grading machine for different fruits and vegetables. M.Sc. thesis. Agric. Mech. Dept. Agric. Fact. Mansora University, Egypt.

Suliman. E. El. R., A. F. El. Sahrigi, and M.M. Mosa, 1998. Engineering factors affecting the development of grading machine for citrus. Integrated local and foreign manufacturing of Agric. Equipment and Machinery 6th Conference of Misr society of Agric. Eng., 21-22 October 1998, (79-90).