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Full length article

Evaluation of a size grading machine for onion

Ghanem T.H. [a], Mohamed M. Bader [a], Elwan A. Darwish [a], Amr A. Elattar [b,*]

[a] Department of Agricultural Products Process Engineering, Faculty of Agricultural Engineering, Al-Azhar University, Cairo, Egypt.
[b] Graduate student, Agricultural Products Process Engineering, Faculty of Agricultural Engineering, Al-Azhar University, Cairo, Egypt.

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ABSTRACT

Onions considered one of the most important economic crops in Egypt. Onion grading is very important for its profit gain to the farmer. As it improves packaging and other post-harvest operations, manual grading of onions is tedious, labor-intensive, and causes many losses. The grading machine for onion evaluated in terms of grading efficiency, cost economics and onions damage percent for Giza 20 and Beheri varieties. The grading efficiency was 96.72%, 94.85 for Giza 20 and Beheri onions respectively, at 2.5 Hz, and at zero degrees an angle of inclination. The damage percent for onions was not observed at different grading conditions in this study.

1. Introduction

In Egypt onion ranks fourth after cotton, rice, and citrus as an export crop. The total cultivated area was 78948 ha the total production was 3081047 Mg, (FAO 2019). Grading of these minor fruits is considered very important as it can fetch higher price to the grower. In addition to grading improves packaging, handling and other post-harvest operations. Grading is separating the material in different homogenous groups according to its specific characteristics like size, shape, color and on quality basis. It saves time and energy in different processing operations and reduces the handling losses during the transportation. Normally fruits ware graded manually in Egypt. Manual grading is an expensive and time-consuming process and even the operation is affected due to non-availability of labors during peak seasons (Narvankar et al., 2005).

Manual grading of onion is a labor-consuming and tedious operation coming with many losses. Therefore, 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).

The fruits and vegetables are generally graded on basis of size and graded fruits are more welcome in export market. Grading could reduce handling losses during transportation. Mechanical grading fruit and vegetables mostly on the basis of size, prevented disease affected and damaged fruit and vegetables when sorted.

Grading done on the basis of size and shape is important for marketing uniform high quality produce. Grading gives direct benefit to all parties concerned in the buying and selling transactions. It is essential to the business of processors, wholesalers and retailers. Consumers get a benefit whenever the packages carry the official grade marking (Schoenemann, 1977).

*Corresponding author.
E-mail address: amrelatar2017@gmail.com (Amr A. Elattar).

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The aim of this study is to develop a prototype for grading onions, evaluate this prototype for two different varieties of onions and determining its optimal operating engineering conditions.

2. Materials and methods

2.1. Raw material

Two of the most popular onion cultivars Giza 20 and Beheri were brought from private farms at Menofia Governorate, Egypt, at the beginning of the summer, 2020 and directly graded.

2.1.1. The onion grader machine construction

A simple device for the classification of onion is designed and developed depending on the size. The following factors were considered while developing the grader:

1. Suitability of the machine for grading a wide range of different onion sizes.
2. Ease of operation and maintenance.
3. Energy efficient and low cost of operation.
4. Minimum damage to onion.

The onion grader consisted of feeding unit, grading unit and collecting unit. The elevation and plan of the onion grader are shown in Figure 1.

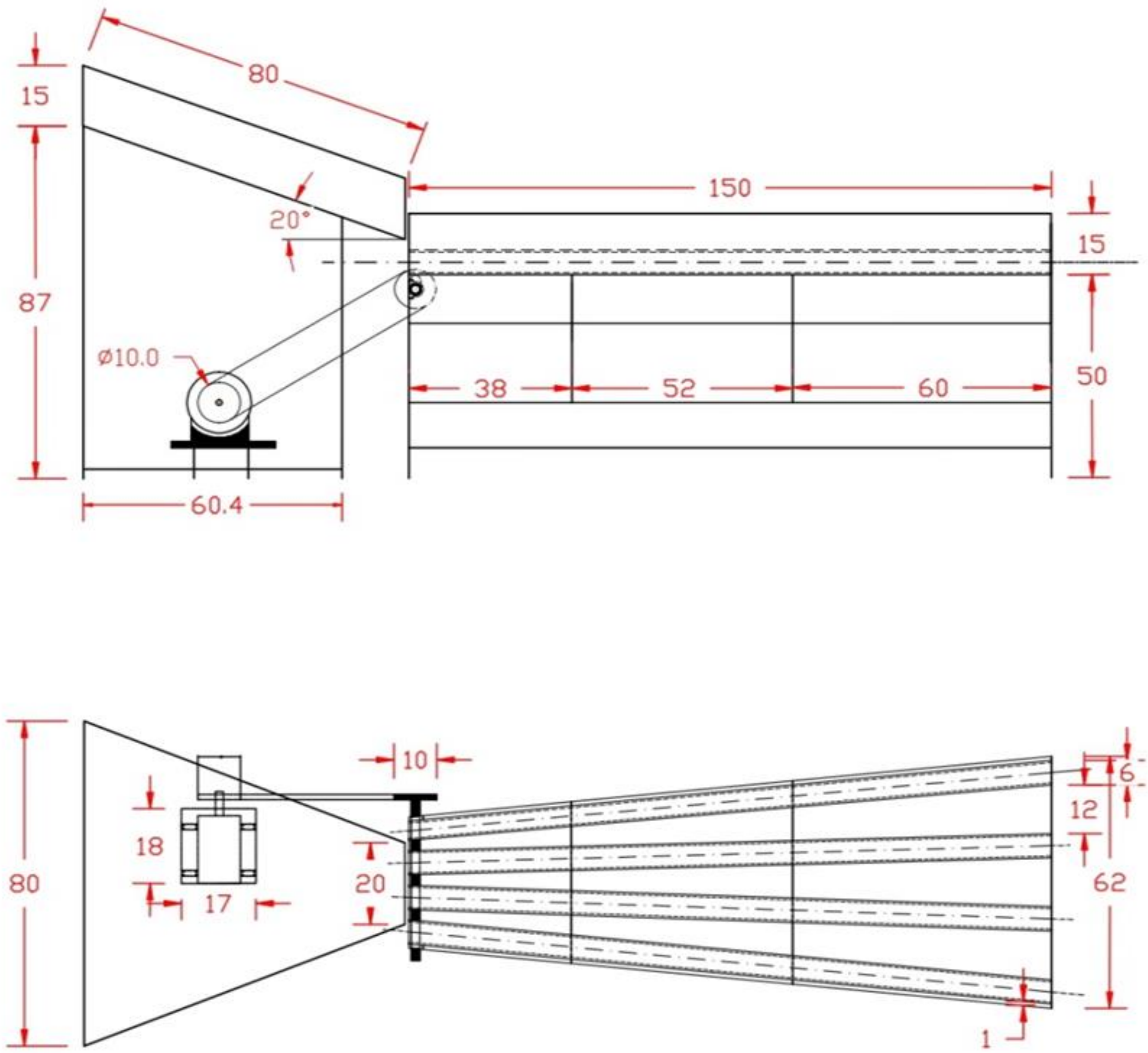

Figure 1. Elevation and plan of onion grading machine.

2.1.1.1. The feeding unit

The feeding unit consisted of a chute installed on a structural frame was fabricated out of mild steel angle section of 40x40x6 mm. The chute was made of 2 mm plywood, having a trapezoidal base of (500 mm for the wider, 200 mm the other end and 800 mm vertical distance) dimensions. In addition, has three sides with a height of 150 mm to avoid bulbs jumping out of the chute.

2.1.1.2. Grading unit

The grading unit consists of tubular grader and vibration system.

The tubular grader

Consists of a four tubes made of PVC with 60 mm diameter and length 1500 mm the tubes installed on a structural frame fabricated out of Mild Steel angle section of 40x40x6 mm and 150 mm height. Both ends of each tube were supported with galvanized iron axis. The tubular grader was allowed to take different inclination angles with horizontal. The distance between the tubes was 25 mm on front of the feeding unit, while the distance 120 mm at the other end

The vibration system

To help easy flow of onions on the tubular grader. The grading unit was pivoted on a cam to be vibrated up and down. The vibration system consists of electric motor (0.5 H.P, 220 V, 50 Hz, 680 RPM, Ins.ci.F, 08774 BET and made in Egypt), a Cam to convert rotational motion to vibrational motion and V-type belt to motion transmission.

2.1.1.3. The collection unit

The collection unit is fixed down the tubular grader to collect the graded onions. The collection unit consists of three troughs made from plywood to collect three different size of onions based on polar diameter namely Small (> 40 mm), Medium (40 – 70 mm) and large (< 70 mm) according to (mostafa and Bahnasawy, 2009), the plywood was chosen to reduce damage at falling onions from tubular grader.

2.2. Measuring Instrumentations

a) Digital venire caliper: used for measuring length and diameter of different onion sizes (accuracy of 0.01 mm).

b) Electrical balance: (accuracy 0.01 g) made in Japan, the balance is weighing up to 5 kg having

c) Protractor: for measuring angles (0-180°) and (accuracy 1°).

d) Stopwatch: stopwatch of (accuracy 1 s) was used to record the grading time.

e) A digital AVO meter: used to measure the consumption of electrical current "A", with accuracy of 0.01A, measuring range (0 - 50 A) and the potential difference (V) of device and the device is made in China.

f) The friction and rolling angles: used to measure the coefficient of friction is the tangent of the slope angle of the changeable friction surface was measured with a protractor.

2.3. Experimental procedures

Two varieties of onion have graded (Giza 20 and Beheri). Prior grading onions was topped to pervert resistance of clogging and movement. This work was carried out on previously development prototype in Ag. Product process Eng. Dept.

In order to study grading of onions and to describe the two previous varieties and to set a database for future processing, some physical and mechanical properties of onions were studied. Properties affecting the grader design were also measured as: grading efficiency "η" (%), onions damage (%) and grading costs "G_c" (L.E/kg) were calculated for all experiments at different the previous variable.

2.4. Experimental design

Experiments were carried out with three inclination angles 0, 5 and 10 degree of grader unit and four vibratory speeds 1.3, 1.7, 2 and 2.5 Hz with two varieties of onions Beheri and Giza 6. A sample of 10 kg in three replicate was taken from each onion variety for proceeding with the grading experiments.

2.5. Calculations

2.5.1. Grading Efficiency (η)

Grading efficiency (η) of the developed grader was estimated on the basis of known feed composition for each decided vibrating motions and angle of Inclination of roller. Under known feed composition test, the onion bulbs of different sizes were selected according to the outlet dimensions and fed to hopper. There were three outlets or collection units collecting the bulbs separated during grading. According to commercial grade as well as the size group, the grades were decided as A (< 40 mm), B (40 to 70 mm), and C (> 70 mm).

After completing the grading, the collected onions were weighed in each aggregate unit and then the grading efficiency was calculated using the following equation (Narvankar *et al.*, 2005).

$$\eta_1 = W_1 / W_t \times 100 \quad (\%) \ldots [1]$$

where,

η_1: Grading efficiency with respect to collection unit of first grade or grade A (< 40 mm) (%)

W_1: Weight of bulbs of grade A.

W_t: The assumed weight falls in grade A.

Similarly, grading efficiency of grade B and C (η2 and η3) was calculated and the overall grading efficiency (η_t) for each rpm with respect to roller inclination was estimated using the following equation (Narvankar et al., 2005).

$$\eta_t = \frac{\eta_1 + \eta_2 + \eta_3}{3} \times 100 \quad (\%) \ldots [2]$$

2.5.2. Cost economics

The grader machine hourly costs were calculated based on the fixed and variable costs of the onion grader by using the following formula (Awady, et al., 2003).

$$C=\frac{P}{h}\left(\frac{1}{a_l}+\frac{i}{2}+t_x+r\right)+(c_p.e)+\frac{m}{200}, \quad (L.E/h) \ldots [3]$$

where,

C: Grading machine hourly cost, (L.E /h).

P: Price of grading machine (L.E)

h: Yearly working hours, which is assumed in the present work to be: (300 days/year × 8 h/day = 2400 h/year).

a_L: Life expectancy of machine, is taken (10 Year).

i: Interest rate/Year. (The bank interest in Egypt), which was about 14%.

t_x: Taxes and overheads ratio, which is assumed 20 %.

r: Repair and maintenance ratio, which is assumed 10 %.

c_p: Power consumed under machine load (kW).

e: Hourly cost/kW.h, (1.30 L.E/kW.h).

m: The monthly average wage, L.E., (2500 L.E/month); and

200: The monthly average working hours.

$$G_c=\frac{\text{grading machine hourly cost, (L.E/h)}}{\text{grading machine productivity, (Mg/h)}} \ (L.E/Mg_{\text{graded onion}}) \ldots [4]$$

where,

Gc: Total cost, (L.E /Mg).

Dollar exchange rate at the time was equivalent of 15 L.E.

2.5.3. Machine grading damage

The percentage of mechanical damage during grading at each rpm with respect to roller inclination were determined by visual observation. The graded bulbs were sorted in respect of damage due to abrasion and the weight of total damage bulbs collected at each collection unit was noted. Thereafter, the damage percentage was estimated using following relation.

$$D_P=\frac{w_{d1}+w_{d2}+w_{d3}}{w_t} \times 100 \quad (\%) \ldots [5]$$

where,

D_P: Damage in percent (%)

W_{d1}, W_{d2}, and W_{d3}: Weight of damaged bulbs collected at A, B and C collection unit, respectively.

W_t: Total weight of bulbs (Mg)

3. Results and discussions

3.1. Grading efficiency of grading machine

Onion grading machine was evaluated in terms of grading efficiency for Giza 20 and Beheri onions varieties. The relationship between grading efficiency and vibratory motions at the three slope angles 0, 5 and 10 degree of grader unit for grading Giza 20 and Beheri onions varieties as show in Figures 2 and 3.

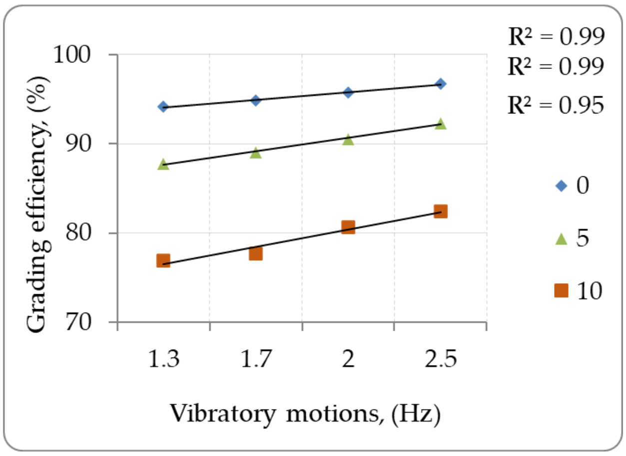

Figure 2. The relationship between grading efficiency and vibratory motions at different slope angles of grader unit for Giza 20 onion.

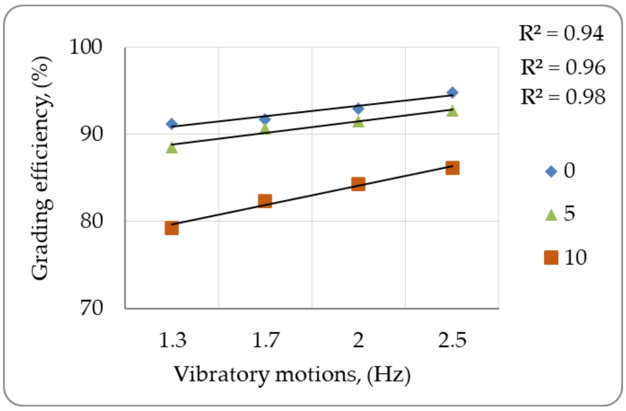

Figure 2. The relationship between grading efficiency and vibratory motions at different slope angles of grader unit for Beheri onion.

The highest values for grading efficiency were 96.72% and 94.85% for Giza 20 and Beheri onion varieties respectively, with vibratory motion 2.5 Hz and grader unit inclination 0°, while the lowest values were 76.93% and 79.27% for Giza 20 and Beheri onion variety respectively with vibratory motion 1.3 Hz and grader unit inclination 10°.

The observed and predicted grading efficiency as affected by vibratory motion and slope angles of grader unit for Giza 20 and Beheri onions as show in Figures 4 and 5. The complete prediction empirical equation of grading efficiency for Giza 6 onion was:

$$\eta=[0.1094(\theta)+0.8898]f+[-1.8689(\theta)+93.987], \quad (\%) \ldots [6]$$

R^2 = 0.944

And the complete prediction empirical equation of grading efficiency (%) for Beheri was:

$$\eta=[0.1041(\theta)+1.0815]f+[-1.2291(\theta)+91.012] \quad , \quad (\%) \ldots [7]$$
$$R^2 = 0.833$$

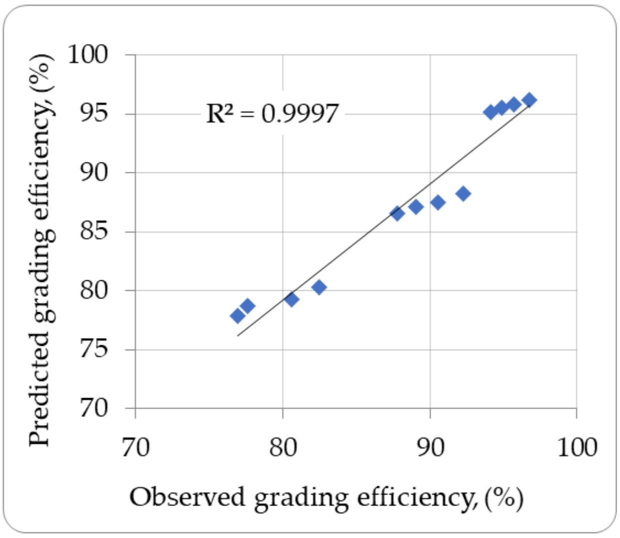

Figure 4. Predicted and observed grading efficiency at different vibratory motion and different slope angles for Giza 20 onion.

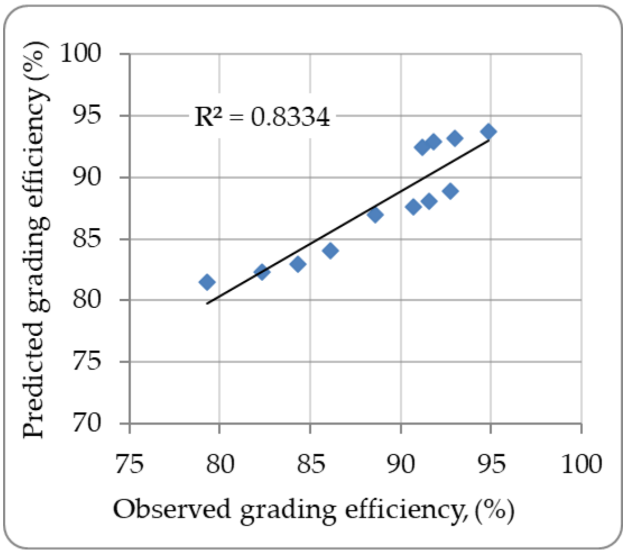

Figure 5. Predicted and observed grading efficiency at different vibratory motion and different slope angles for Beheri onion.

3.2. Economics of grading machine

The grading cost of 29.128 and 19.850 L.E/Mg for Giza 20 and Beheri onions respectively, when 2.5 Hz and 0 degree for grading unit of onions using grading machine, also the grading machine capacity (Mg/h) were 0.461 and 0.545 Mg/h for Giza 20 and Beheri onion respectively. The best fit equations between total cost (L.E/Mg) and vibratory motions at the three slope angles 0, 5 and 10 degree of grader unit for grading Giza 20 and Beheri onion varieties as show in Figures 6 and 7.

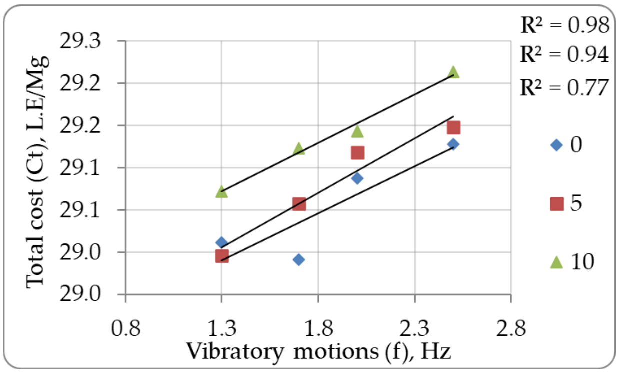

Figure 6. The relationship between total cost of grading machine and vibratory motions at different slope angles of grader unit for Giza 20 onions.

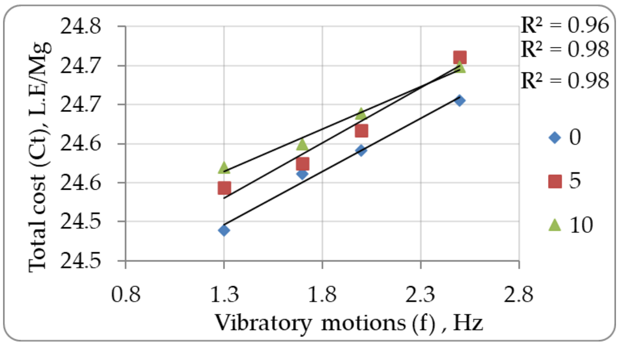

Figure 7. The relationship between total cost of grading machine and vibratory motions at different slope angles of grader unit for Beheri onions.

The highest value for total cost were 29.214 L.E/Mg and 24.711 L.E/Mg for Giza 20 and Beheri onion varieties respectively, with vibratory motion 2.5 Hz and grader unit inclination 10° and 5°, while The lowest values were 28.892 L.E/Mg and 24.489 L.E/Mg for Giza 20 and Beheri onion varieties respectively, with vibratory motion 1.3 Hz and grader unit inclination 0°.

3.3. Grading damage

During the performance tests, no damage was not observed to any onions. Even at the maximum vibratory motions, bulbs were unaffected from collisions, shearing and impact. In order to find out the percent damaged bulbs for each test run, visual observations for assessing the damage due to abrasion, impact and bruising were made. It was observed that there was no damage due to abrasion or impact on bulb and only rare amount of skin removal occurred. The results obtained for all the three replications of each test run are reported and described hereunder.

4. Summary and conclusions

Onion grading is very important because it brings profit to the farmer. As it improves packaging and other post-harvest operations, manual grading of onions is tedious, labor-intensive, and causes many losses, labor-intensive, and costs.

Exporting agricultural products is one of the main objectives of the current policy of the Egyptian government, especially for Europe. In order to be able to achieve this goal, it is necessary to apply appropriate post-harvest techniques for each crop and for onions; it must be well sorted and graded.

This study aims to manufacture a machine with local raw materials for grading onions and to study some of the factors affecting the grading process and to determine the most appropriate factors to obtain the highest efficiency for the grading process.

The study variables are as follows:

1. *Onion varieties:* Two varieties of onion were chosen from the most widespread in Egypt, namely, Beheri (red) and Giza 20 (yellow).
2. *The angle of inclination of the grading unit:* Three angles of inclination of the grading unit were chosen (0, 5 and 10 degrees).
3. *Frequency of vertical vibrational movement:* Four frequencies of vibrational movement were chosen (1.3, 1.7, 2 and 2.5 Hz) at rotation speeds (80, 100, 120, 150 rpm).

The evaluation factors were as follows:

- The efficiency of the grading machine.
- The economics of the grading process.
- Damage resulting from the grading process.

The most important results obtained:

Grading efficiency

The highest grading efficiency was recorded at 96.72% and 94.85% for each of Giza 20 onions and Beheri onions respectively at the highest frequency, which is 2.5 Hz, and at an angle of inclination of zero degrees, in each of the two onion cultivars under study. Whereas, the lowest grading efficiency was 79.93% and 79.27% for both Giza 20 and Beheri onions, respectively, at 1.3 Hz, and at an inclination angle of 10 degrees for both cultivars.

Where a mathematical equation has been reached, through which it is possible to predict the value of the efficiency of the grading process, whether for Giza 20 and Beheri onions respectively:

$$\eta_{Giza}=[0.1094(\Theta)+0.8898]f+[-1.8689(\Theta)+93.987], \quad (\%)$$

$$\eta_{Beheri} = [0.1041(\Theta)+1.0815]f+[-1.2291(\Theta)+91.012], \quad (\%)$$

The economics of the grading process

The results showed that the cost of grading onions affected by both the frequency of the vibratory motion and the angle of inclination of the grading unit for all cultivars. Where the cost of the grading process was 29.128 L.E/Mg, 19.850 L.E/Mg for each of Giza 20 onions and Beheri onions respectively at a frequency of 2.5 Hz, and at an angle of inclination 9 of zero degrees, where there is a big difference between manual grading and grading by machines

Grading damage

During the performance tests, no damage was not observed to any onions. Even at the Frequency, bulbs were unaffected from collisions, shearing and impact.

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تقييم آلة للتدريج الحجمي للبصل

طارق حسين غانم [١]، محمد محمد بدر [١]، علوان علي درويش [١]، عمرو عبد الله العطار [٢]

[١] قسم هندسة تصنيع المنتجات الزراعية، كلية الهندسة الزراعية، جامعة الأزهر، مدينة نصر، القاهرة، مصر.
[٢] طالب دراسات عليا، قسم هندسة تصنيع المنتجات الزراعية، كلية الهندسة الزراعية، جامعة الأزهر، مدينة نصر، القاهرة، مصر.

الملخص العربي

يعتبر البصل من أهم المحاصيل في جميع البلدان وفي مصر يحتل البصل المرتبة الرابعة بعد القطن والأرز والحمضيات كمحصول للتصدير، تعتبر عملية تدريج البصل مهمة جدًا لأنها تجلب ربحاً للمزارع. حيث تعمل علي تحسين عمليات التعبئة وعمليات ما بعد الحصاد الأخرى، يعتبر التدريج اليدوي للبصل عملية شاقة وتستهلك الكثير من العمالة وتتسبب في العديد من الخسائر والعمالة المكثفة والتكاليف.

تصدير المنتجات الزراعية هو أحد الأهداف الرئيسية للسياسة الحالية للحكومة المصرية، وخاصة لأوروبا. ولكي تكون قادرة على تحقيق هذا الهدف فإنه من الضروري تطبيق تقنيات ما بعد الحصاد المناسبة لكل محصول وبالنسبة للبصل يجب أن يتم فرزه وتدريجه جيدًا. وتهدف هذه الدراسة الي تقييم أله بخامات محلية لتدريج البصل ودراسة بعض العوامل المؤثرة على عملية التدريج وتحديد أنسب العوامل للحصول علي أعلي كفاءة لعملية التدريج

وتتمثل متغيرات الدراسة فيما يلي:

١. أصناف البصل: تم اختيار صنفان من البصل الاكثر انتشارا في مصر وهما البحيري (الأحمر) وجيزة ٢٠ (الأصفر).

٢. زاوية ميل وحدة التدريج: تم اختيار ثلاث زوايا لميل منطقة التدريج وهم (صفر، ٥ و١٠ درجة).

٣. تردد الحركة الاهتزازية الرأسية: تم اختيار أربع ترددات للحركة الاهتزازية وهم (١,٣، ١,٧، ٢ و٢,٥ هرتز) عند سرعات دوران (٨٠، ١٠٠، ١٢٠، ١٥٠ لفة/ دقيقة) على التوالي.

وكانت عوامل التقييم كما يلي:

- كفاءة أدلة التدريج.
- اقتصاديات عملية التدريج
- الضرر الناتج من عملية التدريج.

وأهم النتائج المتحصل عليها:

- كفاءة الة التدريج: أوضحت النتائج أن كفاءة التدريج تأثرت بكلا من تردد الحركة الاهتزازية وزاوية ميل وحدة التدريج، حيث تتناسب كفاءة التدريج طردياً مع التردد وعكسياً مع وزاوية ميل وحدة التدريج، حيث سجلت أعلي كفاءة تدريج ٩٦,٧٢٪ و٩٤,٨٥٪ لكل من بصل جيزة ٢٠ والبصل البحيري علي التوالي عند أعلي تردد وهو ٢,٥ هرتز، وعند زاوية ميل صفر درجة في كلا من صنفين البصل محل الدراسة. بينما كانت أقل كفاءة تدريج ٧٩,٩٣٪ و٧٩,٢٧٪ لكل من بصل جيزة ٢٠ والبصل البحيري علي التوالي عند تردد ١,٣ هرتز، وعند زاوية ميل ١٠ درجة لكلاً من الصنفين، حيث تم التوصل الي معادلة رياضية يمكن من خلالها التنبؤ بقيمة كفاءة عملية التدريج لكلا من جيزة ٢٠ والبصل البحيري علي التوالي:

$$\eta_{Giza} = [0.1094(\Theta)+0.8898]f+[-1.8689(\Theta)+93.987], \quad (\%)$$

$$\eta_{Beheri} = [0.1041(\Theta)+1.0815]f+[-1.2291(\Theta)+91.012], \quad (\%)$$

- اقتصاديات عملية التدريج: أوضحت النتائج ان تكلفة تدريج البصل تتأثر بكل من تردد الحركة الاهتزازية وزاوية ميل وحدة التدريج لجميع الأصناف. حيث كانت تكلفة عملية التدريج ٢٩,١٢٨ جنية/ميجا جرام، ١٩,٨٥٠ جنية/ميجا جرام لكل من بصل جيزة ٢٠ والبصل البحيري علي التوالي عند تردد ٢,٥ هرتز، وعند زاوية ميل صفر درجة، حيث هناك فرق كبير بين التدريج اليدوي والتدريج بواسطة الآلات.
- الضرر الناتج من عملية التدريج: خلال اختبارات الأداء لم يلاحظ أي للبصل محل الدراسة، حتى عند سرعة الدوران القصوى، لم تتأثر أصناف البصل من التصادمات.