EVALUATION THE PERFORMANCE OF AN ONION PEELING MACHINE

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ABSTRACT

The aim of the present study is to develop and evaluate an onion peeling and trimming machine to be used in small and medium production units, such as restaurants, hotels and small onion drying units. All peeling experiments of onion were carried out at average moisture contents of 79.6 and 81.1 % (w.b.) for Giza 6 and Beheri onion resp. Onion peeling machine is fabricated, developed and tested. Experiments were carried out with four open flat belt speeds (15, 20, 25 and 30 rpm), onion sizes (small, medium and large) and two of the most popular onion cultivars Giza 6 (white) and Beheri (red). The results showed that values of peeling efficiency, peeling capacity and total cost for Giza 6 onion were more than that of Beheri onion for peeling machine. For Giza 6 onion the results showed that the highest value of peeling capacity was140.61 Kg/h at open flat belt speed of 30 rpm and large onion size, while the lowest value of total cost was 40.14 L.E/Mg at the same operating conditions, Also; the highest value of peeling efficiency was 91.20% at open flat belt speed of 15 rpm and medium onion size.

Keywords: *onion, peeling efficiency, peeling machine.*

1. INTRODUCTION

Onion is one of the most important vegetable crops all over the world, in Egypt, onion is a major export crop. The total cultivated area of onion crop is about 202090 feddan, produced about 3.12 million Mg **(FAO, 2016)**. The main commercial onion products are: dehydrated onion, onion powder, onion flavoring (onion oil and onion juice), onion salt, onion slices, pickled onions, and canned onions, most of these processes can't be done unless onion is peeled.

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World onion production is steadily increasing so that onion is now the second most important horticultural crop after tomatoes. Post-harvest process of onions included several processes: sorting, grading, packing, transporting, storage, peeling and washing. The onion peeling is considered one of the most important and difficult process of post-harvest **(Wang, 1997)**.

Somsen *et al.* (2004) said that the quality of processed fruits and vegetables is highly dependent on the peeling stage. Poor peeling management leads to expensive finished products due to high peeling losses and low quality of finished produce. The ideal peeling method aims to remove the peel with high efficiency and low peeling losses as normally desirable.

On the other hand onion peeling is a value added process that increased nearly 100% by peeling and trimming **(Naik *et al.*, 1997)**.

Srivastava *et al.*, (1997) design and evaluated an onion peeling machine under three different onion feeding rate (chain speed) (60, 80, and 100 onion/min), three different onion size (small, medium and large) and three different onion shape (flat, round and oval). The optimum peeling efficiency of 89% was obtained at 80 onion/min feeding rate, medium onion size and round onion shape.

El-Ghobashy *et al.* (2012) developed and evaluated an onion peeling machine to suit the small and medium processing units. Three different drum rotational speeds (30, 40 and 50 rpm) three different peeling residence times (1, 2 and 3min) and three different batch loads (18, 24 and 30 kg) were evaluated for a batch system. The optimum peeling efficiency of 74.9, 65.24, 80.08 and 85.45% were obtained at 24 kg batch load, 2 min peeling residence time and 40 rpm for small, medium, mixed and large sizes resp.

The aim of the present study is to develop and evaluate an onion peeling and trimming machine to be used in small and medium production units, such as restaurants, hotels and small onion drying units.

2. MATERIAL AND METHODS

A prototype of onion peeling machine is constructed, fabricated, developed and tested in the Faculty of Agricultural Engineering workshop, the experimental part of the present study was carried out in the Agricultural Products Process Engineering Laboratory at the Faculty of Agricultural Engineering Al-Azhar University, Nasr City, Cairo. The following items were considered in the peeling machine design: processes safety, small scale and weight to have more mobility, using local materials to facilitate maintenance, easily refitted and dismantled, no water requirement for peeling and longer life span.

2.1. Materials

Two of the most popular onion cultivars Beheri (red) and Giza 6 (white) were brought from private farms at El-Mahla El-kubra, Gharbia Governorate, Egypt, at the beginning of the season were directly used in the present work.

2.1.1. The onion peeling machine description:

The onion peeling machine is constructed of:

1. **Main frame**

The main frame is made of L shape steel angles (4×4 cm) for carrying the power transmission motors, transmission pulleys, pulleys driving the open flat belt used for feeding process and transmission motors. All parts of the peeling machine are mobile on a frame (245×70 cm) equipped with six wheels to be easy manageable.

2. **Power transmission system**

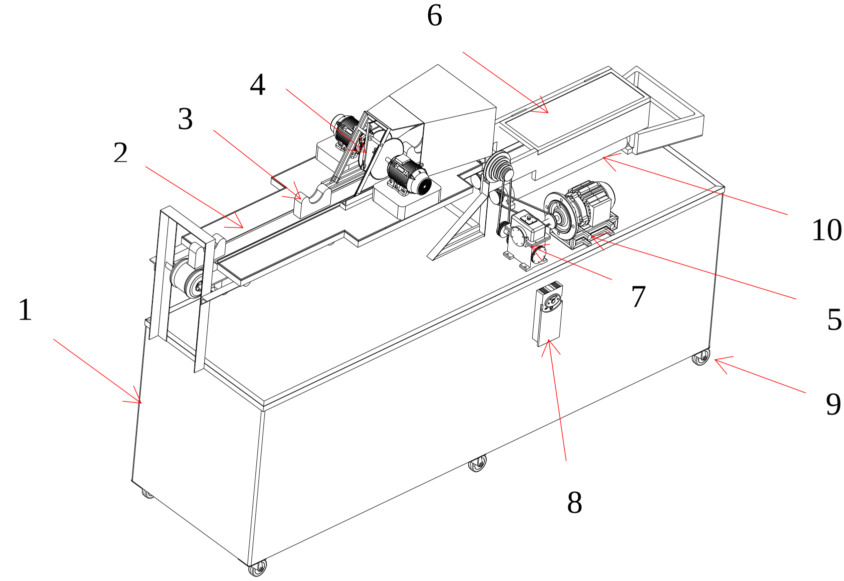
The power transmission system is constructed of main essential motor of 0.375 kW, used for driving one pulley for controlling running speed, and directly used to transform motion of an open flat belt used for feeding mechanism and the two scouring drums. For more controlling the main power transmission motor, an inverter in used for speed controlling from 0 - 1400 rpm. Two small motors of (0.25 kW and 1400 rpm) were also used for driving the cutting knives for the top and tail process.

3. **Top and tail cutting mechanism**

The top and tail cutting mechanism is constructed of an open feeding belt equipped with six half-circular shaped buckets used for feeding onions to the two same cutting saw discs derived inward the belt for increasing supporting force of onions during the cutting process, a supporting arm and pulley system hinged with spring in the mainframe is also used. Two saw disc knives are made of stainless steel of 0.22 cm thick and 18.5 cm diameter derived with two separated motors rotating inward the belt were used for the cutting process.

4. Peeling mechanism design

The scouring mechanism used in the studied prototype is made of two drums 60 cm length and 9 cm diameter, are driven by the main power transmission motor with 500 rpm. The onion peeling machine is shown in Fig. 1.



1.	Mainframe.	6.	Separation mechanism.
2.	Flat belt.	7.	Gear box.
3.	Bucket.	8	Inverter.
4.	Cutting tools "saw knife discs".	9.	Wheels.
5.	Electrical motor.	10.	Friction drums.

Fig. 1: Isometric of onion peeling machine.

2.1.2. Measuring instruments

1) Digital caliper: A digital caliper (accuracy of 0.01mm) made in China, was used to measure the diameter of different onion sizes of the studied cultivars. **2)** A digital balance: Weight of samples were measured by a digital balance, made in Japan. The balance is weighing up to 5 kg having accuracy of (0.01 g). **3)** Electric oven: The moisture content of onion was evaluated by oven drying methods (Venticell55 type made in Germany, 230V, 50/60 Hz, 1250W, 250^{o}C Max. temperature). **4)** Digital tachometer: A digital tachometer was used to measure the rotational speed with rpm of the drum. The measuring range of the tachometer are, 2.5 to 99999 rpm with accuracy of 0.1 rpm through the speed 2.5 to 999.9 rpm and 1 rpm over 1000 rpm. **5)** Stop watch: Stop watch of accuracy 1 s was used to record the peeling time.

2.2. Methods

2.2.1. The experiments procedure

In order to evaluate the developed onion peeling machine, 72 run or replicated treatments were carried out, each run was carried out on 6 onions. The independent variables and their levels for prototype evaluation are shown in Table 1.

Table 1: Independent variables and their levels for evaluating the onion peeling unit.

No.	Independent variables	Replicates	Levels No.	Independent variables Levels
1	Open flat belt speed	3	4	15, 20, 25 and 30 rpm
2	Onion variety	3	2	Beheri and Giza 6
3	Onion size	3	3	Small size 70±3 mm Medium size 80±3 mm Large size 90±3 mm
Total runs = 4 Open flat belt speed × 2 Onion varieties × 3 Onion size ×3 Replicates = 72 runs.				

2.2.2. Peeling machine performance

❖ **Machine peeling capacity**

Machine peeling capacity is defined as the total mass of the onions processed by the machine in an hour. The peeling capacity is depended on onion size and feeding rate. Machine peeling capacity (P_c) was calculated as follows:

$$P_c = \frac{M_i}{t} \quad \text{(kg/h)} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

Where: P_c :Machine peeling capacity,(kg/h); M_i:Initial sample mass, (kg); and t: Time consumed in peeling process, (h).

❖ **Machine peeling efficiency**

Peeling efficiency can be computed according to **(Srivastava *et al.*, 1997)**.

$$P_e = \frac{M_i - M_m}{M_i - M_f} \times 100 \quad (\%) \quad \ldots\ldots\ldots\ldots\ldots (2)$$

Where: P_e: Machine peeling efficiency (%); M_m: Sample mass after machine peeling, (kg); and M_f : Final sample mass, (kg).

❖ Economical evaluation of the onion peeling machine

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

$$C = \frac{P}{h}\left(\frac{1}{a_L} + \frac{i}{2} + t_x + r\right) + (P_r.e) + \frac{m}{200} \quad \text{(L.E /h)} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where:

C) Peeling machine hourly cost, (L.E /h); **P**) Price of peeling 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 %; **P_r**) Power requirements (kW); **e**) Hourly cost / kW.h, (0.4 L.E/kW.h); **m**) The monthly average wage, L.E., (1000 L.E/month); and **200**) The monthly average working hours.

$$Total\ \ cost = \frac{\text{Peeling machine hourly cost}, (L.E/h)}{\text{Peeling machine capacity } (Mg/h)} \quad \text{(L.E /Mg)} \quad \ldots\ldots (4)$$

3. RESULTS AND DISCUSSION

Experiments were carried out on two of most popular onion cultivars Giza 6 and Beheri were brought from private farms with moisture contents of 81.1% and 79.6% (w.b), resp. The performance of the onion peeling machine is characterized by the following parameters.

❖ Evaluating performance of the peeling and trimming machine

1. Peeling capacity

Fig. 2 shows the relation between peeling capacity "P_c" (kg/h) and open flat belt speeds "N" (15, 20, 25 and 30 rpm) at different onion sizes "O_s" (small, medium and large) for Giza 6 and Beheri onion of peeling machine. Generally; the peeling capacity affected linearly by increasing open flat belt speed from 15 to 30 rpm for Giza 6 and Beheri onion of peeling machine. Data takes the form: $P_c = aN + b$ ………. (5)

The highest values of peeling capacity were 140.61 and 134.39 Kg/h for Giza 6 and Beheri onion resp. at large onion size and open flat belt speed

30 rpm. It could be noticed that values of peeling capacity for Giza 6 onion were more than that of Beheri onion for peeling machine.

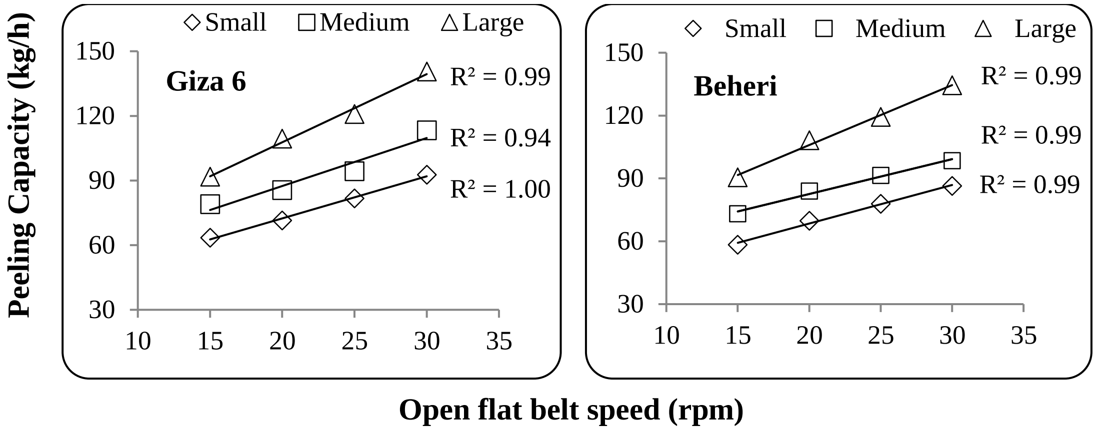


Fig. 2: The relation between peeling capacity and open flat belt speeds.

Drawing the parameter "a" and "b" against the different onion sizes. It was found that power form was satisfied as depicted in Fig. 3.

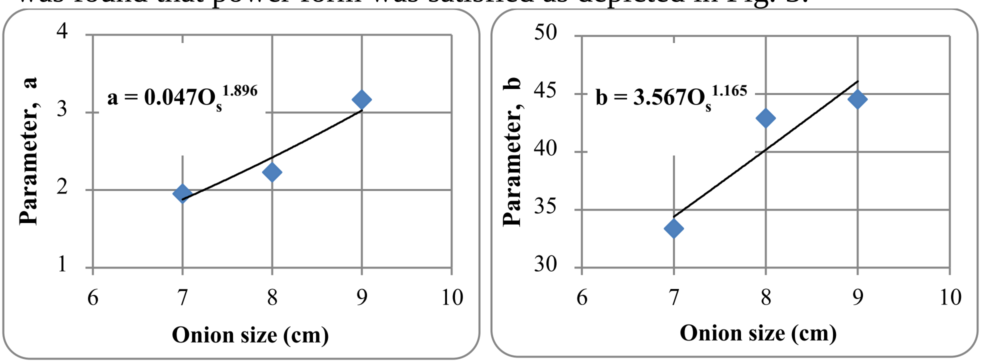


Fig. 3: The relation between parameter "a" and "b" with onion sizes.

The complete prediction empirical equation of peeling capacity was:

$$P_c = [0.047(O_s)^{1.896}N] + [3.567(O_s)^{1.165}] \qquad R^2 = 0.9 \qquad \ldots\ldots (6)$$

Fig. 4 shows the predicted and observed peeling capacity (Kg/h) for Giza 6 and Beheri onion of peeling machine.

2. Peeling efficiency

Fig. 5 shows the relation between the peeling efficiency (%) and open flat belt speeds (15, 20, 25 and 30 rpm) at different onion sizes (small, medium and large) for Giza 6 and Beheri onion.

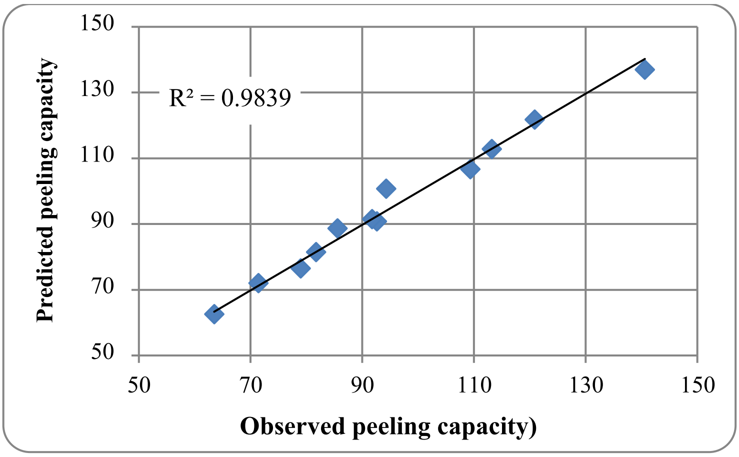


Fig. 4: Predicted and observed peeling capacity peeling capacity (Kg/h) for onion peeling machine.

It is clear that, there are inverse proportional between the rotational speed of driving shaft of the feeding belt and peeling efficiency for small, medium and large onions of the two studied varieties.

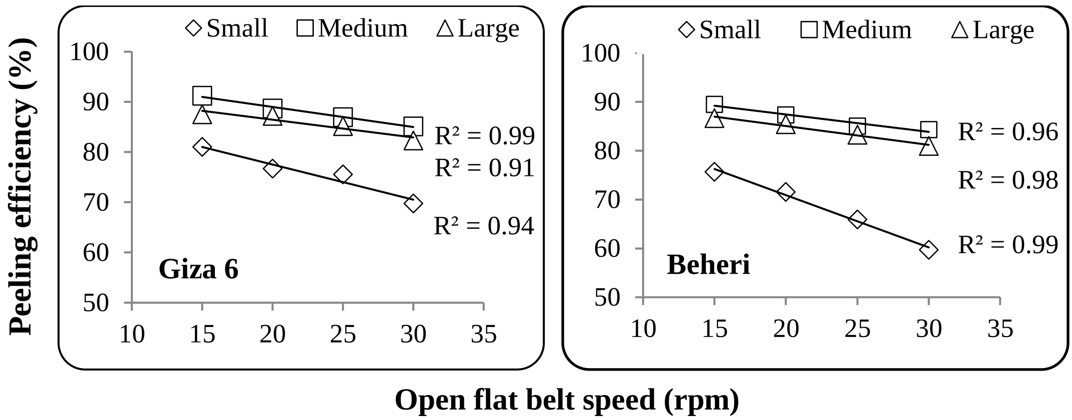


Fig. 5: The relation between peeling efficiency and open flat belt speeds at different onion sizes when Giza 6 and Beheri onion.

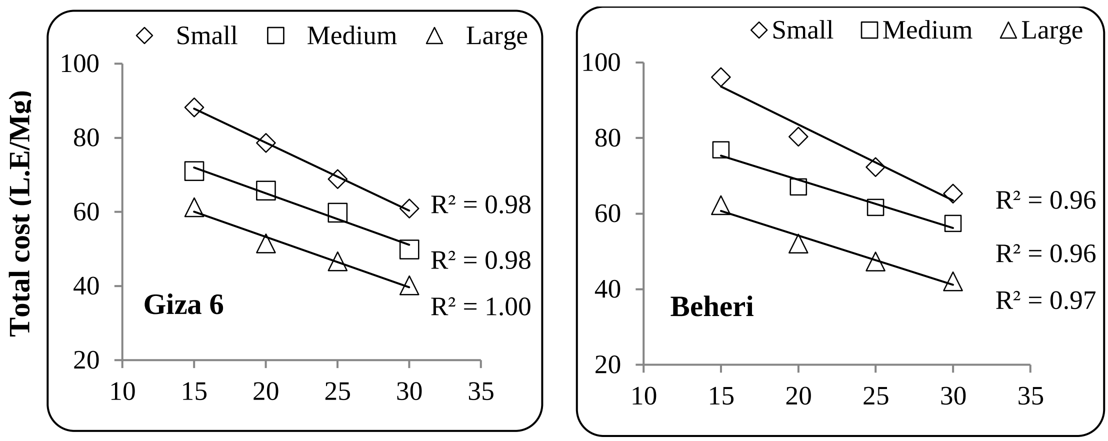
It is also clear that the highest values of peeling efficiency were 91.20 and 89.48 % at medium size and open flat belt speed 15 rpm for Giza 6 and Beheri onion resp. The medium size has higher values than small and large, these results may be related to the constant clearance space 3 cm between scouring drums that is more compatible for machine size than that of small and large sizes. Results accepted with that reported by

(Srivastava *et al.*, 1997). Also; it could be noticed that values of peeling efficiency for Giza 6 onion were more than that of Beheri onion for peeling machine.

3. Cost analysis

Fig. 6 shows the relation between total cost (L.E/Mg) as affected by open flat belt speeds (15, 20, 25 and 30 rpm), onion sizes (small, medium and large) and onion varieties.

Generally; the total cost decreased with increasing the tested speeds and studied onion sizes for Giza 6 and Beheri onion. Results showed that the lowest value for total cost were 40.14 and 42.08 L.E/Mg at operation condition 30 rpm open flat belt speed and large onion size for Giza 6 and Beheri onion resp.



Open flat belt speed (rpm)

Fig. 6: The relation between total cost and open flat belt speeds at different onion sizes for Giza 6 and Beheri onion.

4. CONCLUSION AND RECOMMENDATIONS

This research was carried out to develop and evaluate an onion trimming and peeling machine to be used in small and medium producing units. Large peeling machines with higher investment, huge amounts of peeling water that costly recycled, short onion preservation time are disadvantages of imported peeling machines. On the other hand unavailability of machines for small and medium processing units leads to manual peeling that reflected on higher peeling losses, tedious and time consuming process, extensive labors and costs.In the present study the main purpose is to design and developed a peeling and trimming machine.

The results can be summarized as follow:

- The results showed that values of peeling efficiency, peeling capacity and total cost for Giza 6 onion were more than that of Beheri onion for peeling machine.
- For Giza 6 onion the results showed that the highest value of peeling capacity was140.61 Kg/h at open flat belt speed of 30 rpm and large onion size, while the lowest value of total cost was 40.14 L.E/Mg at the same operating conditions, Also; the highest value of peeling efficiency was 91.20% at open flat belt speed of 15 rpm and medium onion size.
- For attaining best peeling and trimming quality, lower costs and power requirements of Beheri and Giza 6 onions the optimal speed 15 rpm and medium onion size.
- Sizes less than the medium onions should be used in home options, pickling ……etc., due to lower cost feasibility.
- For higher economical feasibility, onion grading and sorting equipment should be added before the peeling machine.
- Onion slicing unit should be also added after the peeling machine for drying units, hotels and restaurants to attain better onion quality.
- More trails should be done to get lower machine size and electronic control units should be also added to get better peeling quality to be kept up with the development of agricultural processing machines.

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الملخص العربى

تقييم أداء ألة لتقشير البصل

طارق حسين غانم [١] ، محمد محمد بدر[٢] ، خالد سيد ناجى[٣] و علوان على درويش[٤]

يعتبر تقشير البصل عملية هامة من عمليات التصنيع المختلفة سواء كان للإستخدام الطازج أو إدخالة في صناعات أخرى مثل التجفيف والفرم والتخليل وانتاج مسحوق ونكهة البصل.

توجد عدة طرق للتقشير وهى اليدوى والميكانيكى والكيميائى (بالجير أو بالأنزيمات) والتقشير الحرارى (باللهب أو بالبخار) ويعتبر التقشير الميكانيكى للبصل أفضل الطرق المستخدمه لما له من مميزات عديدة أهمها الجودة العالية للبصل نتيجة عدم وجود مواد كيميائية متبقيه أو فقد البصل لنكهته نتيجة للتحليل الأنزيمى أو وجود تهتك وخشونة وتجاعيد فى الأنسجة نتيجة الإحتراق الذى يؤثر على جودة البصل الناتج عن هذه الطريقة وتوفير الوقت والجهد والتكاليف المبذولة فى التقشير اليدوى.

لوحظ فى السنوات الأخيرة فى مصر أنه يتم استيراد آلات تقشير البصل ذات الأحجام الكبيرة والتى تستخدم فى المصانع ذات السعات الإنتاجية العالية ولا توجد آلات تقشير وتقليم للبصل فى السوق المحلى لدى الوحدات الإنتاجية الصغيرة والمتوسطة التى تعتمد بالدرجة الأولى على التقشير اليدوى مما يؤدى الى زيادة فى نسبة فواقد التقشير وارتفاع تكاليفه وكذلك ما يتم من مشاكل عن عدم وجود العمالة المدربة لذلك. تهدف هذه الدراسة الى تطوير وتقييم آلة لتقشير وتقليم البصل (قطع القمة والجذر) تتناسب مع متطلبات الوحدات الإنتاجية الصغيرة والمتوسطة ويتم تقييم أدائها فنياً واقتصادياً لتناسب الغرض المصممة من أجله.

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- **المتغيرات تحت الدراسة:**

١. أصناف البصل: تم اختيار صنفان من البصل وهم الأكثر انتشاراً فى مصر وهم بحيرى وجيزه ٦.
٢. حجم البصل: تم تقسيم البصل الى ثلاث فئات تدريجية بالنسبة للقطر القطبى للبصل على النحو التالى (صغير ٧٠±٣مم، متوسط ٨٠±٣مم ، كبير ٩٠±٣مم).
٣. سرعة سير التغذية ذو الأوعية للبصل: تم اختبار أربعة سرعات ١٥ ، ٢٠ ، ٢٥ ، ٣٠ لفة/دقيقة.

- **أهم النتائج المتحصل عليها:**

١- السعة الإنتاجية لآلة التقشير:
أوضحت النتائج أن إنتاجية الألة تتأثر بشكل ملحوظ بسرعة سير التغذية وحجم البصل حيث كانت أعلى إنتاجية للألة ١٤٠،٦١ و ١٣٤،٣٩ كجم/س عند سرعة سير التغذية ٣٠ لفة/د والاحجام الكبيرة للبصل لكلاً من البصل الأبيض والأحمر على الترتيب. كما تم التوصل الى علاقة للتنبؤ بالانتاجية كانت على النحو التالى:

$$P_c = [0.047(O_s)^{1.896}N] + [3.567(O_s)^{1.165}] \quad R^2 = 0.9839$$

٢- كفاءة آلة التقشير:
تأثرت كفاءة التقشير بكلا من سرعة سير التغذية وحجم البصل وأوضحت النتائج أن الكفاءة تتناسب تناسب عكسى مع سرعة سير التغذية وأن الأحجام المتوسطة للبصل هى الأعلى كفاءة يليها الأحجام الكبيرة ثم الصغيرة، حيث سجلت أعلى كفاءة تقشير ٩١،٢٠ و ٨٩،٤٨ % عند سرعة سير التغذية ١٥ لفة/د والاحجام المتوسطة للبصل لكلاً من البصل الأبيض والأحمر على الترتيب.

٣- التقييم الاقتصادى:
أوضحت النتائج أن تكلفة تقشير البصل تتأثر بكل من سرعة سير تغذية البصل والأحجام المختلفة للبصل حيث أن تكلفة التقشير تتناسب عكسياً مع كلا من سرعة سير التغذية وكذلك حجم البصل وسجلت السرعة المنخفضة ١٥ لفة/د أعلى جودة برغم إرتفاع تكلفتها إلا أن الأحجام المتوسطة هى الأفضل حيث أنها ذات جودة مرضية وتكلفة منخفضة نسبياً.