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MECHANIZATION OF OLIVE FRUIT GRADING: A CYLINDRICAL GRADING MACHINE

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ABSTRACT

Grading of olive fruits is important for export and local marketing. Grading parameters were length, width, thickness, and weight of olive. The mechanical grading, reduce the period needed to sort the olive varieties compared to manual grading, and the olives price depend on its size.

The cylindrical grading machine for olive fruits was manufactured, and tested at the Agricultural, Engineering Department, Faculty of Agriculture, El-Mansoura University. On the other hand, the experiment was carried out at Kafr-Awd, Aga, Dakahlia Governorate. The machine was tested in grading of Agize, Manzanillo and Picual olive varieties. The grading process was based on fruit parameters such as mass and dimensions and machine parameters such as grading cylinder rotation speed, grading cylinder slope and grading cylinder length. The grading efficiencies of all the olive fruit varieties under study increased with increasing the length and decreasing the tilt angle of grading mechanism. Result indicated the maximum grading efficiencies were 94 %, 92 % and 91 % for, Manzanillo, Agiza, Picual olives varieties, respectively. These values were obtained at grading cylinder length of 600-mm, cylinder rotating speed of 8 r.p.m, and grading cylinder tilt angle of 0.0175Rad.

INTRODUCTION

Olive's varieties are of great nutritional value. They are important sources of carbohydrate, vitamins and minerals. Also, olive is considering one of the main sources of oil. The Cultivated area of olive trees (*Oleo uropea*) increased rapidly in the last decade (Ministry of Agriculture, 1999). The cultivated area of olives reached 1034608 feddan producing about 288.027 metric tons. New reclaimed lands represent 73.47% of total production area in Egypt, and 70.34 % of total production.

Grading is defined as the process, which separated the fruits into different sizes based on their dimensions, volume and weight according to the standards or marketing requirements. Grading of size and quality of fruits is important for export and local marketing and for price determination. There are two methods of olive fruits grading like manual or mechanical grading. Mechanical grading was classified based on the difference in physical characteristics such as length, width, thickness, and weight. The mechanical grading was expected to reduce the period needed to sort the olive varieties compared to the manual one. Many types of machines were available for grading fruits and vegetables, but most of them are expensive for farmers and small factories of olives. Amin (1994) developed and tested a grading machine consisted of rotating cylinder and perforated concave to grade potato, onion and orange crops. The machine was tested in grading of potato crop. The obtained results showed that crop parameters such as tubers dimensions and mass and machine parameters such as (cell area and shape, drum speed, slope of drum axle and drum length) have a significant effect on grading. Mosa (1998) designed and fabricated grading machine for orange and Egyptian lime by using diverging bar or rollers cylinder. The obtained results showed that optimum speed of feeding conveyor was 70 rpm. The most suitable lines for the grading unit was cylinders system and the most suitable tilt angle of grading unit was ranged from (3°to 6°). Ladaniya, and Dass (1994). A rotating grading machine separated fruit into 3 grades on the basis of diameter: ≤ 6, 6.1-7.0 and 7.1-8.0 cm. Stored fruits were evaluated for mass loss, decay and sensory properties. Mechanization of the processing of mandarins saved time and reduced the amount of wax used and the overall costs. Manual size grading was still more accurate, although mechanical grading operated at a rate of 1 ton of fruit per hour. Manually processed fruits showed the highest decay as a result of bruising. Weight loss in mechanically waxed fruits was slightly higher due to inadequate wax coverage.

The main objective of the present study was to develop and evaluate performance of belt grading machine to grade olive varieties of Agize, Manzanillo and Picual. This objective was achieved through the following:

1-Studying some physical and mechanical properties of three Egyptian olive varieties (Agize, Manzanillo and Picaul).

2-Developing a cylindrical grading machine suitable for these varieties of olives.

3-Assessment and evaluation of the performance of the developed machine for different operational conditions.

4-Performing cost analysis for the developed machine.

MATERIALS AND METHODS

The present study was carried out at Kafr-Awd, Aga, Dakahlia Governorate. The experiment was divided into two major stages.

The first stage was the study of some physical properties, such as shape size, mass, volume, and bulk density, and mechanical properties such as rolling angle, repose angle and firmness to determine essential standards for developing the belt grading machine for olive fruits. Three varieties of olive fruits were used in this study, which were Agize Manzanillo, and Picual. The olive fruits were obtained from Qaroon, Fayoum Governorate during the harvesting season (August/September) of 2002 and 2003.

The second stage of experiments was to test and evaluate the performance of belts grading machine. The operational conditions of belts grading machine were as follows:

1. The rotating speeds were selected by conducting a primary experiment on the cylindrical grading machine for two cylindrical diameter, 475 and 355, mm.
2. The rotating speeds were 4, 8, 12 and 16 r.p.m.

3. Tilt angles were selected by primary experimental at the cylindrical grading machine at the angles 0.175, 0.052, 0.087and 0.122 Rad. which are equivalent to 1, 3, 5 and 7 degrees, respectively.
4. Lengths of the grading mechanism were 300, 450 and 600 mm.
5. All treatments were carried out under a constant feeding rate of 540 Kg/hr.

A schematic diagram of the prototype of the grading machine is show in figure 1.

1. Electric motor
2. reduction pulley
3. Drive pulley
4. Internal cylinder
5. External cylinder
6. First outlet
7. Second outlet
8. Third outlet
9. Feeding hopper
10. Drive shaft
11. Bearing
12. Reduction shaft

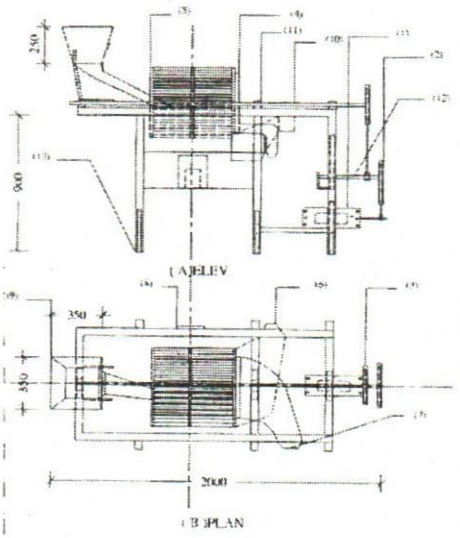


Figure 1: Schematic diagram of the prototype cylindrical grading machine

The machine frame consisted of steel hollow rectangular bars of 50, 30 and 3 mm welded together. The frame was 1000 mm long, 750 mm wide and 900 mm high. It contained three outlets for the three grades of olive fruits.

The hopper was manufactured to feed the fruit into the grading unit with dimensions of 350, 350 and 250mm for length, width and height, respectively. The hopper was made of galvanized steel sheet of 1 mm thickness. The inner face of the hopper was covered with rubber to reduce the impact damage.

The grading unit consisted of two different diameter rotating cylinders one inside the other, to grade the olive fruits into three sizes. Each cylinder was supported by three steel rings. The distance between each two adjacent rings equaled to 300 mm. The cylinders were fixed on the drive shaft.

The external cylinder was 600 mm long. It had an inner diameter of 475 mm and the external diameter was 480 mm. A rubber coated steel bars were distributed at an equal distance of 21 mm, on its circumference, and they were fixed by welding. The diameter of rubber steel bars was 6 mm.

The internal cylinder was 650 mm long. It had an inner diameter of 355 mm and an external diameter of 360 mm. A rubber coated steel bars were distributed at an equal distance of 18 mm on its circumference, and it were fixed by welding.

A 0.25Kw and 220 volts electrical motor was used. It was provided with a reduction system to rotate at 300 r.p.m to drive the grading machine. The power was transmitted from the motor to the grading system by means of (V) belts and different sizes of pulleys.

Physical and mechanical properties of olive fruits were determined according to the following procedures.

One hundred olive fruit sample was taken randomly from the three varieties under study. The shape of each variety was studied in terms of length (L) and diameter (d) by using sliding caliper (± 0.05 mm). The obtained data were used to calculate the shape index of each sample (s.x.=L/d) for olive according to IOOC, 2000. Shape index values less than 1.25 were considered spherical. However, shapes index values between 1.25 and 1.45 were considered ovoid, and at shape index bigger than 1.45 was classified as elongated.

The average weight of one each individual olive was obtained by weighing 100.

The actual olive fruits volume was measured by using 100cm^3 capacity graduated beaker. The graduated beaker was filled with water to a certain level, and then the olive was completely immersed in the beaker using a pen and a thread. The actual olive volume was obtained based on the displacement of water for each fruit. Real density of the fruit was calculated using the equation (D=Mass/Volume) of Buyanov and voronyk (1985).

Mechanical properties

Rolling angle was measured by using an inclined plane with two types of surfaces (steel and rubber) and two positions. Position "A" in which the long axis of fruit was laid parallel to the direction of motion, while in position "B" the long axis of fruit was laid perpendicular to the direction of motion. By placing the fruit on the horizontal surface of the inclined plane one by one and gradually increasing the angle of surface inclination, the fruit began to roll, and that angle was considered as the rolling angle of the fruit (Buyanov and voronyk 1985).

Repose angle was measured by using a rectangular box (40 × 40 × 60 cm^3), which was kept in the vertical position and the free surface of the fruits was leveled .The box is gradually tilted into the horizontal position. Then the free surface of the olive fruit makes an acute angle with respect to the horizontal position. Repose angle was estimated by measuring the angle between the free surface and the horizontal plane.

Fruit firmness was estimated by applying a force to each sample of the investigated varieties by using a portable hand tester (hardness tester. No 174806) Fruits were pressed by the end of the tester (diameter 5mm); meanwhile the analog reading was increased with increasing the pressure of the fruit until the fruit is cracked. At this point the analog reading was considered as fruit firmness.

Machine performance

The grading efficiency was calculated by classification of olive fruits into three categories (15 to 18, 18 to 21 and 21 to 26 mm). The grading efficiency was determined according to Amin, 1994.

$$\eta = \frac{M_1}{M} x100 \qquad 1$$

Where:

η = Grading efficiency of fruits, %;

M_1 = Mass of the classified fruits for each outlet (kg).

M = Total mass of fruits for each outlet in the machine in kg.

The total efficiency of the machine was calculated using the following equation:

$$\eta = \frac{M_1 + M_2 + M_3}{M} x100 \qquad 2$$

Where:

η = Total grading efficiency of the machine, %

M= Total mass of fruits for all outlets in kg.

$M_1+M_2 + M_3$= Masses of the classified fruits for first, second, and third outlets.

Grading capacity

The grading capacity was calculated according to the equation Amin's equation, 1994, as follows:

$$C = \frac{M}{T_G} x60 \qquad 3$$

Where:

C = Grading capacity of the machine (kg/ hr);

M = Mass of classified fruit (kg);

T_G= Grading time (min).

The mechanical damage was considered as the visible damage to human eyes after each pass of the olive fruits through the grading machine. The tested samples were marked and stored for one day in a refrigerated room to examine the damage.

The consumed power (kW) was estimated by using the sup clamp meter-300k to measure the line current strength (I) and the potential difference value (V), that were used to calculate the total consumed power and the useful power according to Platezehiem, 1979.

Fixed costs (deprecation, interest on investment, housing, insurance and taxes) and running costs (repair and maintenance, electricity, and labor) are the major capital input for most farmers. Grading cost in L.E./h or in L.E./ton for the proposed grading machine was estimated according to the Ministry of Agric., 1995.

RESULTS AND DISCUSION

1. Physical properties of fruits:

The relationships between mass of olive varieties, length and diameter were studied and the data were analyzed. Results showed a positive linear relationship between mass and the above mention parameters as shown in Figures 2 and3, respectively. The obtained equations relating mass and length, mass and diameter and mass with length and diameter are listed in tables 1, 2 and 3.

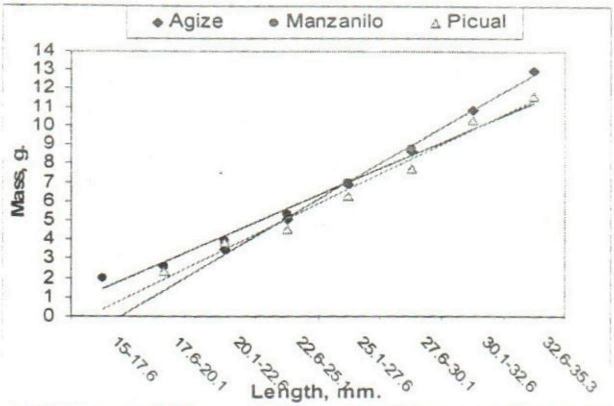


Figure 2: The relationship between mass and lengths of olive varieties.

Table 1: Equations relating mass and length and R^2 for olive varieties

Relation	Varieties	Equations	R^2
Fruit mass and length.	Agize	M = 0.7403 L -13.617	0.9974
	Manzanillo	M = 0.5557 L - 8.3258	0.982
	Picual	M = 0.6213L - 8.3258	0.98

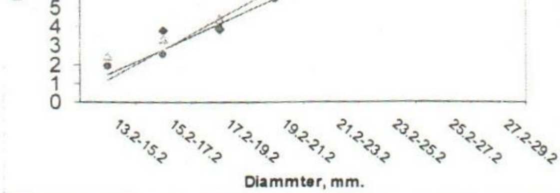


Figure 3: The relationship between mass and diameter of olive varieties.

Table 2: Equations relating mass and Diameter and R^2 for olive varieties

Relation	Varieties	Equations	R^2
Fruit mass and Diameter	Agize	M = 0.8027 D - 10.991	0.9732
	Manzanillo	M = 0.6675 D - 8.6781	0.9921
	Picual	M = 0.753 D - 9.6601	0.9668

Table 3: Equations relating mass, length and diameter and R^2 for olive varieties

Relation	Varieties	Equations	R^2
Fruit mass, length and Diameter	Agize	M = 2.677L + 6.2D -13.683	0.9732
	Manzanillo	M = 2.018L + 4.273D – 8.275	0.981
	Picual	M = 2.745L + 5.08D – 11.311	0.9668

Table 4: Equations relating volume, length and R^2 for olive varieties.

Relation	varieties	Equations	R^2
Fruit volume, and length	Agize	V = 0.7027 L - 12.718	0.9849
	Manzanillo	V=0.5661 L - 8.996	0.9604
	Picual	V= 0.5969 L - 10.478	0.9763

The relationships between volume, length and diameter of olive varieties were studied and analyzed. Results showed a linear positive relationship between volume and previously mentioned parameters as presented in figures 4 and 5 respectively. The attained equations relating volume and length, volume and diameter and volume with length and diameter are listed in tables 3, 4, 5.

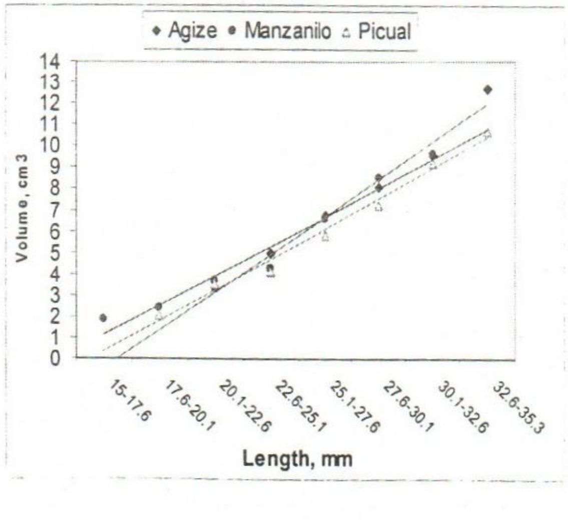


Figure 4: the relationship between volume and length of olive varieties.

Table 5: Equations relating volume, diameter and R^2 for olive varieties.

Relation	varieties	Equations	R^2
Fruit volume and diameter.	Agize	V = 0.8048D - 11.309	0.9815
	Manzanillo	V=0.6627 D - 8.8759	0.981
	Picual	V= 0.7009 D - 9.0732	0.974

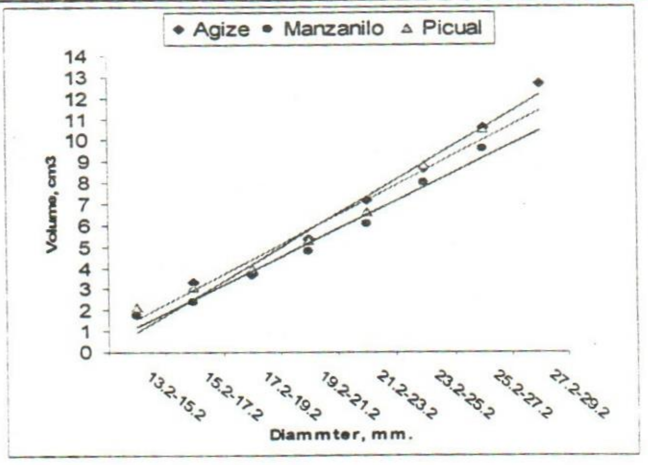


Figure 5: The relationship between mass and lengths of olive varieties.

Table 6: Equations relating volume, and both length and diameter and R^2 values for olive varieties.

Relation	varieties	Equations	R^2
Fruit volume, length and diameter.	Manzanillo	V = 1.381 L + 5.184D – 8.36	0.973
	Agize	V = 2.62 L + 6.417D – 14.081	0.952
	Picual	V = 2.745 L + 5.08D – 11.311	0.958

The relationships between mass of olive varieties and volume were studied and analyzed. Results showed a positive relationship between mass and volume as presented in Figure 6. Regression analysis was carried out and equations relating volume and mass are demonstrated in table 7.

2. Mechanical properties

a. Repose angle

The highest values of repose angle were 31.3, 30.38 and 32.56 degrees for Agize, Manzanillo, and Picual varieties, respectively. The surface roughness, shape and size of olive varieties played important roles on repose angle values.

b. Rolling angle

The maximum values of rolling angles for rubber surface were 14.1 and 7.45, degree for Picual variety at positions A and B, respectively. The corresponding values for steel surface were 12.38 and 6.59 degrees for positions A and B, respectively. Also lower rolling angle was obtained for Agize and Manzanillo varieties.

c. Firmness for olive fruits

The average values of firmness for the different olive varieties were determined. The mean values of firmness force were 1.25, 0.704 and 0.705, N/mm² for olive varieties Agize and Manzanillo and Picual, respectively. In other words, the highest average firmness value was attained with Agize olive variety.

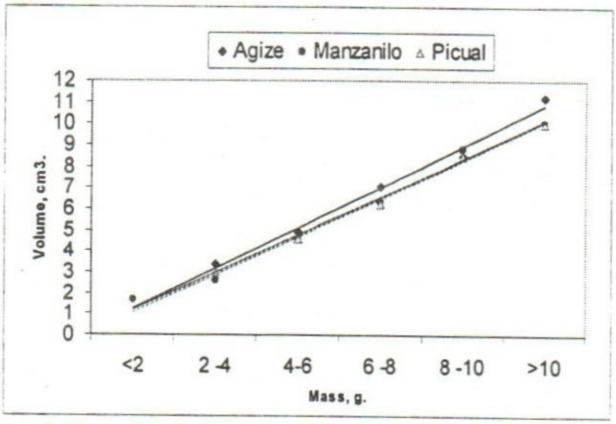


Figure 6: the relationship between volume and mass of olive varieties.

Table 7: Equations relating volume and mass and R^2 for three olive varieties under study.

Physical Properties	varieties	Equations	R^2
Fruit volume and mass	Agize	V = 0.717 M + 0.8638	0.9788
	Manzanillo	V = 0.6987 M+ 0.4398	0.9412
	Picual	V = 0.6528 M+ 0.8601	0.9379

3. General evaluation of the grading machine

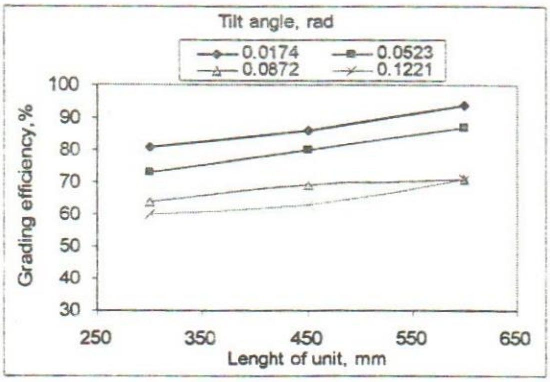
The grading machine was tested for grading efficiency for grading the previously mentioned olive varieties. The results could be discussed as follows:

a. Efficiency of cylindrical grading machine

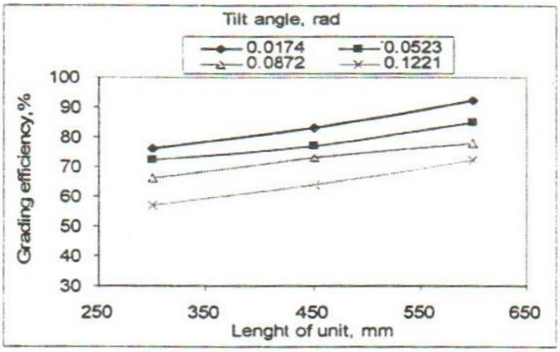
The maximum grading efficiencies were 94 %, 92 % and 91 % for the three olives varieties under study (Manzanillo, Agiza, Picual), respectively. These values were attained at a grading cylinder length of 600 mm, a cylinder rotating speed of 8 r.p.m, and a grading cylinder tilt angle of 0.0175 Rad.

It was clear that the machine grading efficiency increased with increasing the length, and decreasing the tilt angle of the grading mechanism, figure 7. These conditions might result in optimizing the kinetic energy in proportion to the mass of olive that might result in increasing the grading efficiency. A speed of 8 r.p.m, a tilt angle of 0.0175 Rad., and a length of 600 mm, resulted in a kinetic energy such that olive fruits moved on the grading surface at suitable feeding rate.

Manzanillo



Agize



Picual

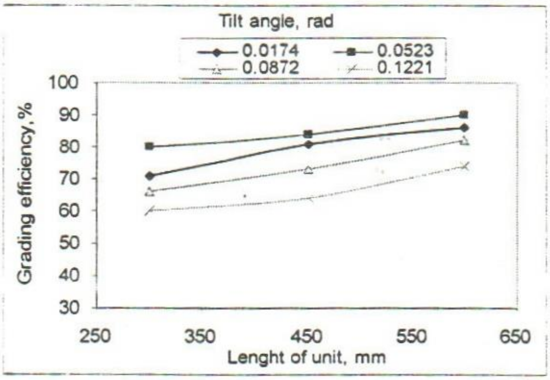


Figure 7: Effect of tilt angle and length of cylindrical unit on grading efficiency at rotating speed of 0.1333 Rad/s (8 r.p.m) for the used olive varieties.

b.Capacity of grading machine

Results indicated that of primary testes the optimum feeding rate was 150 g/s (540 Kg/h) for all olive varieties under study.

c.Power consumption

The power consumption value of the grading unit was reported as 0.195 kW.h for all varieties. The power consumed was measured at optimum operating condition.

d.Mechanical damage for olives

Average mechanical damage values were 2.25, 1.39 and 2.05% for Manzanillo, Agize and Picual varieties, respectively.

4.Cost estimation

From the economic standpoint, choosing a machine is dependant upon its purchase price, labor and its capacity. The use of cylindrical grading machine was evaluated and costs were summarized in table 8.

Table 8: Cost analysis for the cylindrical grading machine

Item		costs
Fixed costs	Deprecation and interest costs, L.E / year.	72
	Housing and insurance costs, L.E / year.	34.4
Total Fixed costs L.E / year.		106.4
Total Fixed costs L.E / h.		0.133
Running cost	Repair and maintenance costs, L.E / h.	0.09
	Energy (electricity) costs L.E / h.	0.0273
	Labor costs L.E / h.	1.5
Total variable costs L.E / h		1.617
Total costs L.E / h		1.764
Total grading costs of olive varieties L.E / ton.		3.253

CONCLUSION

Both mass and volume were positively related to length and diameter of olive fruits. In addition, a positive relationship was found between mass and volume of olive fruit. All the olive fruit varieties under study were having increasing trends with increasing the length and decreasing the tilt angle of grading mechanism at speeds of 8, 12 and 16 r.p.m.

Grading efficiencies for all sizes were maximized at a tilt angle of 0.052 Rad. and at a speed of 4 r.p.m. Nevertheless, the grading efficiency values were minimized at tilt angles of 0.087 Rad. and 0.122 Rad. and at the same speed mentioned before. Comparing the grading efficiencies for different olive varieties it was obvious that both physical and mechanical properties affected the grading efficiency.

The maximum grading efficiency was obtained at a grading cylinder length of 600 mm, a cylinder rotating speed of 8 r.p.m, and a grading cylinder tilt angle of 0.0175Rad.

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ميكنة تدريج الزيتون:آلة التدريج الأسطوانية

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تعتبر عملية تدريج الزيتون من أهم العمليات اللازمة للحفاظ على جودة ونوعية المنتج النهائي سواء فى حالة إعداده للتصدير أو الاستهلاك المحلي. حيث تتوقف جودة المنتج بعد عملية التصنيع على الفترة الزمنية من الحصاد إلى التدريج ثم التصنيع وكذلك تعتمد القيمة السعرية على مدى تساوى أحجام للثمار داخل العبوة الواحدة سواء كان للتصدير أو الاستهلاك المحلى.
وذلك يهدف البحث إلى تطوير آلة التدريج الأسطوانية لثمار الزيتون لتلائم المزارع الصغيرة وكذلك المعامل الأهلية الصغيرة.
وقد تم تجربة آلة التدريج الأسطوانية على ثلاث أصناف من محصول الزيتون (مانزانيللوا – عجيزى – بيكوال) ودراسة تأثير كل من أربع سرعات و ثلاث أطوال و أربع ميول لوحدة التدريج على كفاءة التدريج.

ومن الدراسة تم الحصول على النتائج الآتية:

-مواصفات التشغيل للآلة ذات التدريج الاسطوانية:
تم الحصول على أقصى كفاءة لوحدة التدريج للثلاث الأصناف ٩٤% ، ٩٢% ، ٩١% على التوالي عند معدل تغذية ١٥٠جم/ث، ، زاوية الميل ٠,٠١٧٥ زاوية نصف قطرية وسرعة ٠,١٣٣٣ لفة / ث و طول لوحدة التدريج ٦٠٠مم.
-التلف الميكانيكي للثمار:
كانت نسبة تلف للثمار للأصناف الثلاثة (٢,٢٥% - ١,٣٩% - ٢,٠٥%) على التوالي.
- الطاقة المستهلكة في التشغيل:
بلغت الطاقة الكهربية المستهلكة فى التشغيل ٠,١٩٥كيلو وات / الساعة.
- الإنتاجية الكلية للآلة والتكاليف:
١- بلغت الإنتاجية للآلة عند معاملات التشغيل الموصى بها ٠,٥٤ طن/ ساعة.
٢- بلغت تكلفة إنتاج الطن الواحد ٣,٢٧ جنيه مصرى .