DEVELOPMENT OF AN ELECTRICAL HAND-HELD OLIVE HARVESTER

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ABSTRACT

The objective of this study was developed a hand held olive harvester suitable for small farms. The portable machine was designed, fabricated and evaluated for its performance and techno-economic feasibility. Some physical and mechanical properties (dimensions, mass, fruit detachment force / mass ratio) of olive fruits that are related to the mechanical harvesting were measured and considered in the machine design. The developed machine was evaluated at three levels of head speed (700, 1100 and 1500 rpm) and two types of head length (H_1 has stick length of 6 cm and H_2 has stick length of 17 cm). The evaluation criteria were: productivity (Pm), fruit removal percentage (FR) and fruit damage percentage (FD), consumed energy (CE) and harvesting cost (HC). From the obtained results, it is deduced an equation and contour chart for the harvesting machine to predict the suitability of the machine to removal the fruit with different olive variety. The most suitable working parameters of the machine at 1100 rpm and 1500 rpm with (H_2) where the maximum value of evaluation parameter were Pm of 91.5 kg h^{-1}, FR of 97.7 %, FD of 6.23 %, CE of 1.31 W h $kg^{-1}$and HC of 0.26 L.E kg^{-1}.

Keywords*: olive; hand-held; harvesting; fruit detachment; fruit damage.*

INTRODUCTION

Olive tree (***Olea europaea L.***) is one of the most important crops in all the Mediterranean countries. In Egypt, olive is a key part of the agriculture sector, where a cultivated area of about 67293 of hectares, and an average year production of 694.3 thousand tons (***FAOSTAT, 2018***). Olive production faces many problems, some of them related to the low product price and high production costs. So, it is important to reduce costs and improve fruit quality. The harvesting operations of olive are the most costly and they contain olive fruit detachment from the tree and collection of the detached olives.

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The olive harvesting mechanization systems allow reducing costs where it needs less manpower and increasing quality (better productivity rates) (***Amirante and*** **Tamborino,** ***2012***). The olive harvesting cost is the most expensive operation, it represents between 25 and 60% of total cropping cost (***IOOC, 2015***). In Egypt, the most olives farms are harvested by the manually methods. ***Vieri and Sarri (2010)*** mentioned that the hand harvesting has low productivity which reaches 50% -70% of the cultivation revenue. ***Özarslan et al., (2001)*** reported that hand harvesting represents about 50% of the total production costs and 50-60% of the total labor requirement for harvesting operations. The best harvesting operation is definite as the ability to harvest more than 90% of the olive fruits, in the shortest time, lowest number of labor, minimum damage to the olive fruits and minimum risk for labor (***Mansour et al.***, ***2018***). ***Hegazy (2009)*** reported that harvesting methods can be classified to: manual, simple hand-held equipment, fully mechanized. ***Famiani et al. (2010***) stated that the common operating harvesting machine of olive can be divided to two types: oscillating or vibrating or turning combs, and shaking hooks. ***Deboli et al. (2014a)*** stated that hand held olive harvesters are: beaters, combs and hooks. Beaters are machines with an oscillating head equipped with thin sticks in carbon fibre; harvesting is obtained by direct impact of sticks on olives or by vibration transmitted to the willowy branches. ***Deboli et al. (2014b)*** stated that the hand harvest of olives is one of the most expensive operations in the table olives production, and the electric hand machines can be replaced the hand harvesting. ***Paschino et al. (2010)*** carried out a preliminary study on the use of electric hand held harvesters, equipped with titanium undulating teeth coated with silicone. Olive harvesting by hand-held harvester is used with a low capital investment and when full mechanization is not possible. It represents a minimum level of mechanization because the machine is carried by the operator (***Famiani et al., 2010***). ***Famiani et al. (2008***) and ***O'brien et al., (1986)*** mentioned that the factors affecting the mechanical harvesting of tree fruit were frequency, amplitude, direction of shaking, fruit size and detachment force to fruit weight ratio. Factors affecting mechanical olive harvesting are tree shape, canopy density,

orchard density, pruning and the cultivar (***Tombesi et al, 2002 and Ferguson et al, 2010***).

Farinelli et al., (2012) reported that the factors that affected the fruit detachment were variety, maturity, fruit weight, detachment force, geometry of the fruit, tree pruning and specifications of the harvester.Another important parameter is the limb length, it is length from the attachment point with fruit bearing branch to the attachment point with each fruit from the bearing branch (***Castillo-Llanque and Rapoport, 2009***) ***Visco et al., (2004)*** demonstrated that the major problem of mechanical olive harvesting; is generating sufficient fruit removal force transmitted to the olive abscission zone, to detach the olive fruit without damage. Fruit detachment is mainly caused by three oscillation modes; the pendulum, the tilting, and the rotational (or twisting) (***Zhou et al., 2016***). The objective of this study was to design and evaluate a hand-held machine for harvesting olive in small farms.

MATERIALS AND METHODS

The developed hand- held harvesting machine had been designed, manufactured and evaluated at the Faculty of Agriculture, Omar El-Mukhtar University, El-Beida – Libya. The main criteria for designing the prototype of machine for harvesting fruits were: easy design, simple to use, low weight, high productivity, less fruit damage, and low operating costs.

3.1 Tree and fruit parameters related to harvesting olives fruit

3.1.1 Dimensions of the olive tree

An important factor for designing the machine is to know the characteristics of the olive tree. The measurements were carried out on 15 trees of manzanillo cultivar. The trees had the same dimensional and morphological characteristics and were planted on a 12 × 12 m spacing. The dimensional characteristics of olive trees are reported in table (1).

Table (1): Main dimensional characteristics of the olive trees

Trunk circumference (cm)	Trunk Height (m)	Canopy diameter (m)	Tree Height (m)	Limb length (cm)
340 ± 45	1.6 ± 0.3	11.3 ± 1.6	5.0 ± 0.4	15

3.1.2 Physical and mechanical properties of olive fruit

A sample of 100 mature olive fruits was collected randomly to measure some physical and mechanical properties of fruit which related to the designing of harvesting machine.

The ratio of fruit detachment force to fruit mass (R_{Fm}) is used to decide the suitability of olive fruit for mechanical harvesting. The fruit detachment force was measured by using the hand dynamometer with 50 N capacity. The hand dynamometer was attached to the selected fruit and a pulling force was gradually increased until the fruit was separated. The maximum force was recorded as the static detachment force. Each detached fruit was then weighed. The ratio of the (R_{Fm}) was calculated using following equation:

$$R_{Fm} = \frac{F}{m} \qquad \textbf{(1)}$$

Where

R_{Fm} : The ratio of the fruit detachment force to mass, N g^{-1}.

F : Fruit detachment force, N.

m : Fruit mass, g.

3.2 Force analysis of olive fruit detachment

It was proposed to the mass of tree limb is ignored in the analysis; and hence, Fruit motion trajectory is namely pendulum motion.

The detachment of the olive fruit is entirely governed by tensile forces acting on the fruit, and detachment occurs when the internal forces due to the motion of the fruit become greater than the fruit detachment force (***Tsatsarelis, 1984***). An oscillated olive fruit has two forces acting on it. One is downward force of gravity. The second is tension in the limb which changes in both size and direction as the fruit swings. When fruit swings through the bottom of its motion path, the fruit has maximum speed and requires the maximum force to hold it in its circular path.

The centripetal force is a combination of the tension force from the limb and the fruit weight of the fruit. The magnitude of the centripetal force on the pendulum changes as the fruit swings back-and-forth, because the component of fruit weight that is along the radius changes (Fig. 1).

At any fruit position, when the limb makes angle θ with the vertical, the fruit is moving slower than at equilibrium and the centripetal force is thus lower than at equilibrium. The centripetal force is given by the following equation:

$$F_{\underset{\text{at }\theta}{\text{centripetal}}} = T_{\underset{\theta}{\text{at}}} - mg\cos\theta \qquad \textbf{(2)}$$

Where

T : Tension force exerted on limb olive, N.

m : Mass of olive fruit, kg.

g : Acceleration gravity, m sec^{-1}.

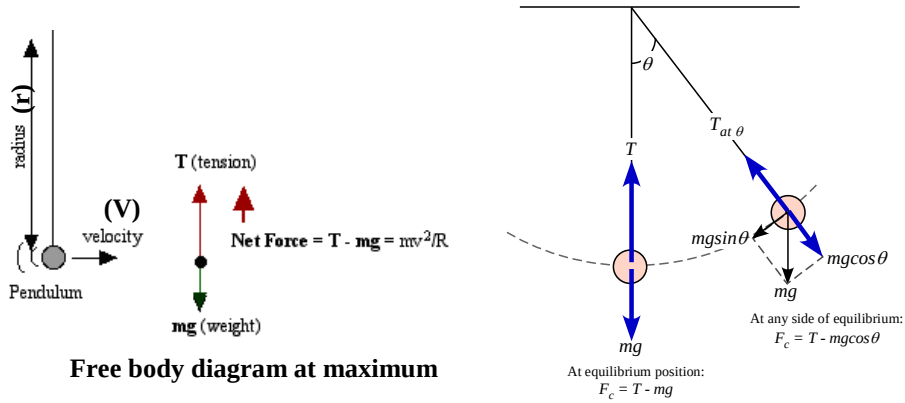


Fig. (1): Fruit motion under oscillation motion.

The maximum centripetal force at the bottom of its swing, because at the equilibrium position is the fruit is moving the fastest, and $F_{\text{centripetal}}$ is greater because speed is greater than the maximum centripetal force, it is given by following equation:

$$F_{\underset{\text{at equilibrium}}{\text{centripetal}}} = T - mg \qquad \textbf{(3)}$$

The net centripetal force is directed toward the center of the circular motion and its magnitude can be calculated by the following equation:

$$F_{\text{centripetal}} = mr\omega^2 = \frac{mv^2}{r} \qquad \textbf{(4)}$$

Where

V : The linear velocity of olive fruit, m sec^{-1} $= \dfrac{2\pi\, r\text{N}}{60}$.

N : Velocity of the head, rpm.
ω : Angular velocity of olive fruit, rad sec^{-1}.
r : Length of peduncle, m.

According to Newton's Third Law of Motion, action and reaction are equal and opposite. Therefore, the olive fruit must exert a force radially outwards and equal magnitude of centripetal force. This force is known as centrifugal force (Fc) and it equals to the centripetal force.
If olive fruit makes the pendulum motion, the fruit would be detached if the centrifugal force becomes greater than the static tensile force (The fruit detachment force). Equation (4) can be rewritten as the following equation:

$$v^2 = (\frac{F}{m}).r \quad \textbf{(5)}$$

By applying the pervious equation in the harvesting olive fruit, the fruit will be detached when the square linear velocity of the olive fruit is higher or equal the value of (F/m.r), it can be written as the following equation:

$$\frac{v^2}{10} \geq (\frac{F}{m}).r \quad \textbf{(6)}$$

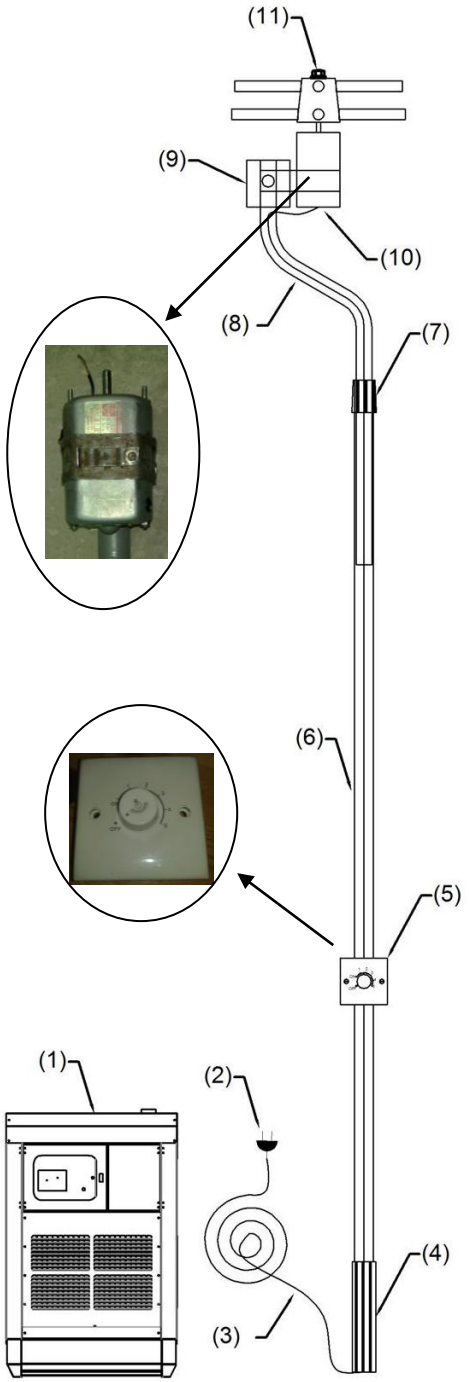
Where

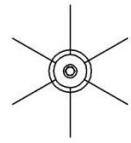
V : The linear velocity of the head harvester, m $sec^{-1} = \frac{2\pi r\mathrm{N}}{60}$.
N : Velocity of the head, rpm.
F/m : Detachment force to mass ratio of olive fruit, N g^{-1}.
r : Length of limb, cm.

By applying the previous equation in the head of the machine, the square linear speed of the head ($V^2/10$) should be higher or equal to the value $(\frac{F}{m}.r)$ of olive fruit variety to get fruit detachment.

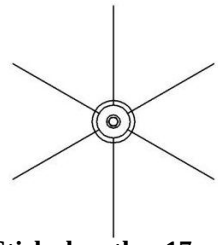
3.3 Developed harvesting machine

The manufactured machine for harvesting the olive fruits consists of the following main parts: a) Harvesting mechanism, b) Extension rod, and c) Power unit. Figure (3) shows the developed machine and its specifications.





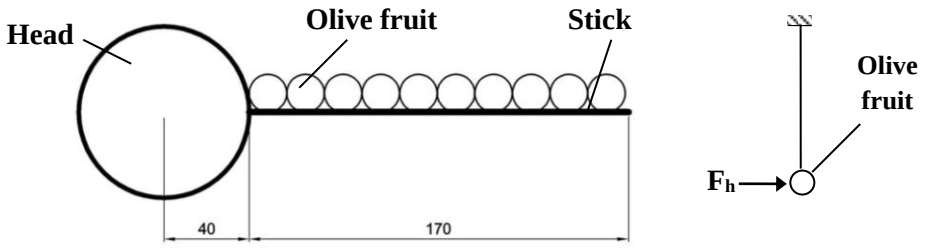
Head 1: Sticks length = 6 cm



Head 2: Sticks length = 17 cm

11	1	Rotary Headcarrying 6 elastic thermoplastic sticks	
10	1	Motor 60 Watt- 2000 rpm	
9	1	Base Motor	
8	1	Extension rod 2,40m length up to 3,4m with (Extension)	Al
7	1	Locking Nut	Plastic
6	1	Main rod	Al
5	1	Regulator Switch	
4	1	handle	Plastic
3	1	Electrical cable	
2	1	Socket	
1	1	Portable Generator 700 W	
Itemref	Quantity	Title/Name	Material
Designed by Dr./Mohamed Ibrahim		Checked by	

Fig. (2): The electrical hand-held harvester.



Dims. in mm

Fig. (3): Head (H_2) of olive harvester.

3.3.1 The olive harvester

The machine had one handle and it was gripped by one operator's hand and a telescoping rod up to a maximum length of 2.9 m.

The harvesting mechanism contains 6 elastic sticks that allow for easy and deep access to all types of foliage without getting caught in the branches. The elastic sticks fixed with the head.

There are two harvesting heads (Fig. 2) were used. The first head (H_1) has diameter of 10 mm and length of 6 cm. The second head (H_2) has diameter of 10 mm and length of 17 cm.

3.3.2 The required power of the developed machine

- Let take head (H_2) that has stick length of 17 cm as shown in Fig. (3).
- The number of fruit that stick can moves olive at simultaneously fruits = stick length/ fruit diameter = 10 fruits.
- The required force (F_h) to oscillate the one fruit = 0.05 N (it was measured by using dynamometer).
- It can calculate the torque for one stick of the head by the following equation:

$$T = \sum_{i=1}^{10} F_h.r_i = F_h \,.\, r_{av} \,.\, N_f \qquad \textbf{(7)}$$

Where

T : Torque for one stick of the head, N-m.

F_h : Required force to oscillate the one fruit, N = 0.05 N.

r_i : The distance from the center gravity of fruit and the center of head at fruit number (i).

i : Number of fruit i = 1,2,3,…..10.

r_{av} : The average distance from the center gravity of fruit and the center of head at fruit, m = 12.5 cm.

N_f : Number of fruits move by one stick = 10 fruit.

Total torque of the head = 0.05 N × 0.125 m × 10 fruit × 6 sticks = **0.375 N-m**.

The required power (P) was calculated by the following equation:

$$P = \frac{M_t \times 2\pi N}{60} \quad \textbf{(8)}$$

Where

P : The required power, W.

M_t : Torsional moment, N-m = 0.375 N-m.

N : Speed of head, rpm = 1500 rpm.

From the previous equation the required power (P) was calculated as **58.9** watt.

3.3.3 Power unit and electrical source

A small- sized electric motor (AC, 220 V – 60 watt - 2000 rpm) is used to operate the head mechanism

The electric motor is driven by a gasoline generator (220 V – 700 watt) through electrical wires passing inside pipes of telescopic rod. The operation regulated switch was fixed on the lower pipe of the frame rod in a suit place for operator. The function of the regulated switch is controlling the speed of harvester head.

3.4 Evaluation criteria

The performance of developed machine was measured by machine productivity, fruit removal percentage, fruit damage percentage, consumed energy and harvesting cost.The evaluation was done under the following variables as shown table (1).

Table (1): Experimental variables for evaluating the machine.

Variables	Levels
Harvesting head type.	(H_1), (H_2)
Head speed, rpm.	700, 1100, 1500

3.4.1 Machine productivity

The total mass of detachment fruits using machine was recorded. The total harvesting time includes selecting, detaching fruit and the time required for moving machine between olive trees inside the field. The productivity of operated machine was calculated as follows:

$$P_m = \frac{W}{T} \quad \textbf{(9)}$$

Where

P_m : Productivity, kg h^{-1}.

W : Mass of harvested fruit, kg.

T : Total harvesting time, h.

3.4.2 Fruit removal percentage (FR)

It was calculated by the following equation (***Polat et al. 2007***):

$$FR = \frac{K_1}{K_1 + K_2} \times 100 \quad \textbf{(10)}$$

Where

F_R : Fruit removal percentage, %.

K_1 : The mass of detachment olive fruit by the machine, kg $tree^{-1}$.

K_2 : The mass of olive fruit which staying on the branch, kg $tree^{-1}$.

3.4.3 Fruit damage percentage (FD)

Fruit damage includes visual inspection and the fruit appears broken to the naked eye (***Srivastava et al., 2006***). Fruit damage was calculated by the following equation:

$$FD = \frac{md}{mt} \times 100 \quad \textbf{(11)}$$

Where

FD : Fruit damage percentage, %.

m_d : Total mass of fruit damage, kg.

m_t : Total mass of fruit harvested by the machine, kg.

3.4.4 Consumed energy (CE)

The required electric power under working load (RP) was calculated as ***Chancellor (1981)*** by the following equation:

$$RP = V \times I \times \cos\theta \quad \textbf{(12)}$$

Where

RP : The required power for operating the machine, watt.

V : Potential difference, Voltage (I phase = 12 voltage).

I : Current intensity, Amperes.

$\cos\theta$: Power factor (0.64).

A digital clamp meter and voltmeter were used for measuring current intensity and voltage respectively.

The consumed energy (CE) is specific power per unit capacity; it was calculated by using the following equation:

$$\text{Consumed energy (W.h kg}^{-1}) = RP/P_m , \quad \textbf{(13)}$$

3.4.5 Harvesting cost (HC)

The harvesting costs of olive is expressed in terms of cost per hour and cost per unit of olive (1 kg). Machine cost was determined using the fixed costs and variable costs according to ***Srivastava et al. (2006)***. The hand harvesting cost (L.E Kg^{-1}) was recorded based on the labor daily salary and its productivity. The harvesting cost was determined using the following equation:

$$\text{Harvesting cost (L.E kg}^{-1}) = \frac{\text{Total cost (L.E day}^{-1})}{\text{Labor productivity (kg day}^{-1})} \quad \textbf{(14)}$$

RESULTS AND DISCUSSIONS

3.1 Olive fruit properties

Table (3) reports the some physical and mechanical properties of the harvested olives.

The mean value of detachment Force (R_{Fm}) for olive fruit with is 6.7 N. So the minimum supporting load at olive stem-twig joints would be probably sufficient to detach the fruit by using rotational head of developed machine.

Table (3): Physical and mechanical properties of olive fruits.

Parameters	Values
Fruit length (L), cm.	**2.13**
Fruit diameter (d), cm.	**1.72**
Volume (v), cm^3.	**3.16**
Fruit mass (m), g.	**3.10**
Fruit detachment force (F_f), N.	**6.7**
Fruit detachment force to mass ratio (R_{Fm}), N/g.	**2.16**

3.2 Performance characteristics of the harvesting machine

Fig. (4) shows the calculated value of ($V^2/10$ = F/m . r) that imparted on an olive fruit by using olive harvesting machine at different levels of head speed values and the length stick of the head. It may simply expect fruit detachment to occur as the inertial force due vibration exceeds the static tensile force required for fruit detachment (**6.7** N for ripe fruits, as listed in Table 3).

By applying rotational head machine, the minimum value of ($V^2/10$) would be equal (F/m. r), to get probably sufficient for detachment fruit.

With any olive variety, it can calculate the value of (F/m. r) and comparing this value with Fig. (4), it can be expected the removal efficiency of the developed machine and if it is suitable with this olive variety.

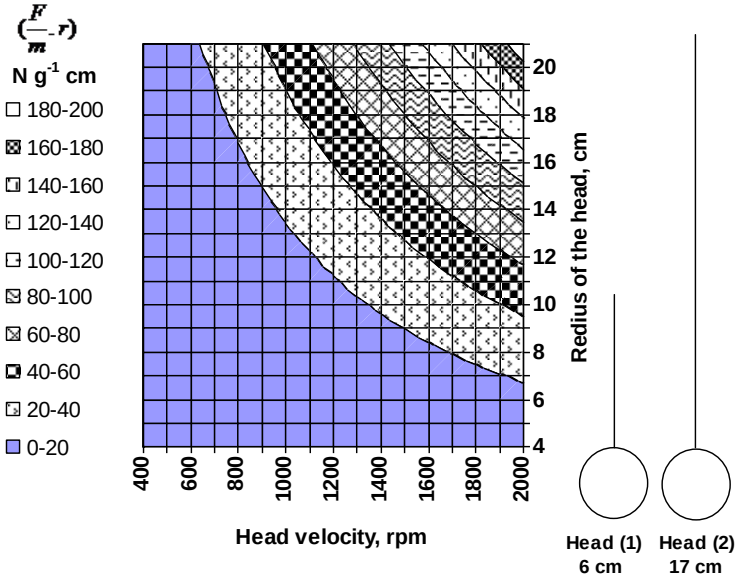


Fig. (4): Performance characteristics of the harvesting machine, that calculated value of (F/m . r).

3.3 Machine productivity (Pm)

Fig (5) shows the productivity of developed machine. The machine productivity ranged from 45.9 to 91.5 kg h^{-1} with head speed of 700 to 1500 rpm and different head types (H_1, H_2). The (Pm) was the least at the lowest head speed of 700 rpm and increased with increasing speed. This

is due to increasing the impacted fruit by increasing the head speed. The (Pm) increased with change the head H_1 by H_2, this due to increase the stick length of head from 6 cm to 17 cm, so increasing the number of impacted fruits in the harvesting fruit.

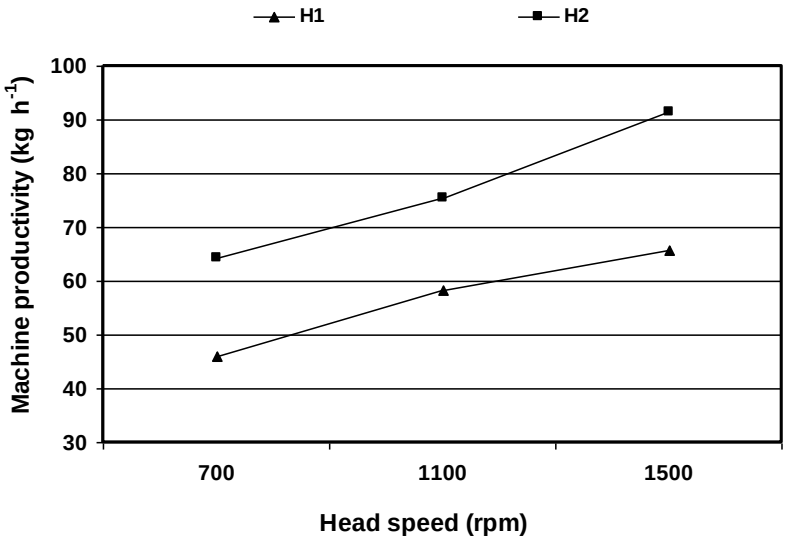


Fig. (5): Effect of speed and type of head on machine productivity.

3.4 Fruit removal percentage (FR)

Fig (6) shows the fruit removal percentage (FR) of developed machine. The (FR) ranged from 80.41 to 97.7 % with head speed of 700 to 1500 rpm and different head types (H_1, H_2). The (FR) was the least at the lowest head speed of 700 rpm and increased with increasing speed. This is due to increasing the impacted fruit by increasing the head speed. The (FR) increased with change the head H_1 by H_2, this due to increase the stick length of head from 6 cm to 17 cm.

3.5 Fruit damage percentage (FD)

Fig (7) shows the fruit damage (FD) of developed machine. The (FD) ranged from 4.5 to 6.23 % with head speed of 700 to 1500 rpm and different head types (H_1, H_2). The (FD) was the least at the lowest head speed of 700 rpm and increased with increasing speed. This is due to increasing the impacted fruit by increasing the head speed. The (FD)

increased with change the head H_1 by H_2, this due to increase the stick length of head from 6 cm to 17 cm so, increasing in the damage fruit.

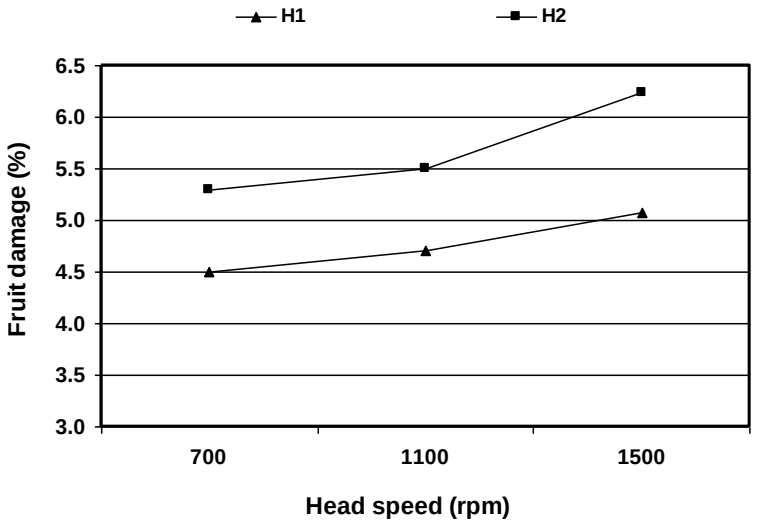


Fig. (6): Effect of speed and type of head on fruit removal percentage.

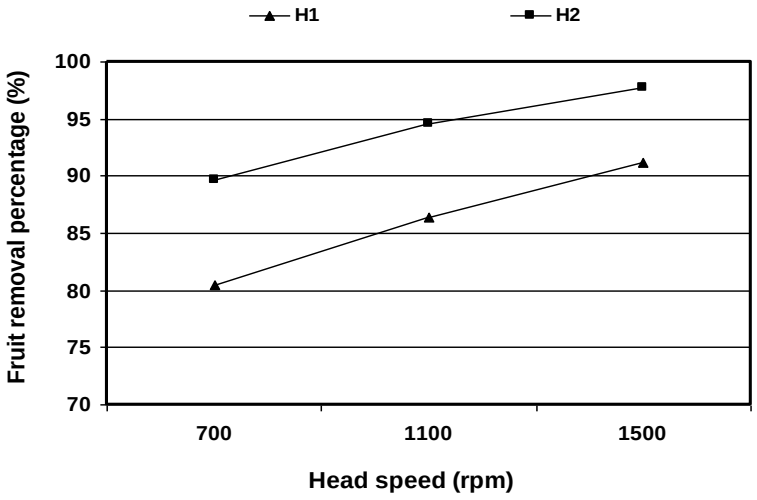


Fig. (7): Effect of speed and type of head on fruit damage.

3.6 Consumed energy (CE)

Fig (8) shows the consumed energy (CE) of developed machine. The (CE) ranged from 0.66 to 1.31 W h kg^{-1} with head speed of 700 to 1500 rpm and different head types (H_1, H_2). The (CE) was the heights at the lowest head speed

of 700 rpm and decreased with increasing speed. This is due to productivity increased by increasing the head speed the. The (CE) increased with change the head H_1 by H_2, this due to increase the stick length of head from 6 cm to 17 cm so, increasing in the harvested fruit. In this study, the productivity and fruit damage level are the two concerned factors to evaluate the selected head speed and head type. The H_2 could remove more fruits but also produce higher fruit damage of 6.3 %. Compared to H_1 with lower productivity can get similar low fruit damage removal. It demonstrates that using the head H_2 at ranges from 1100 to 1500 rpm.

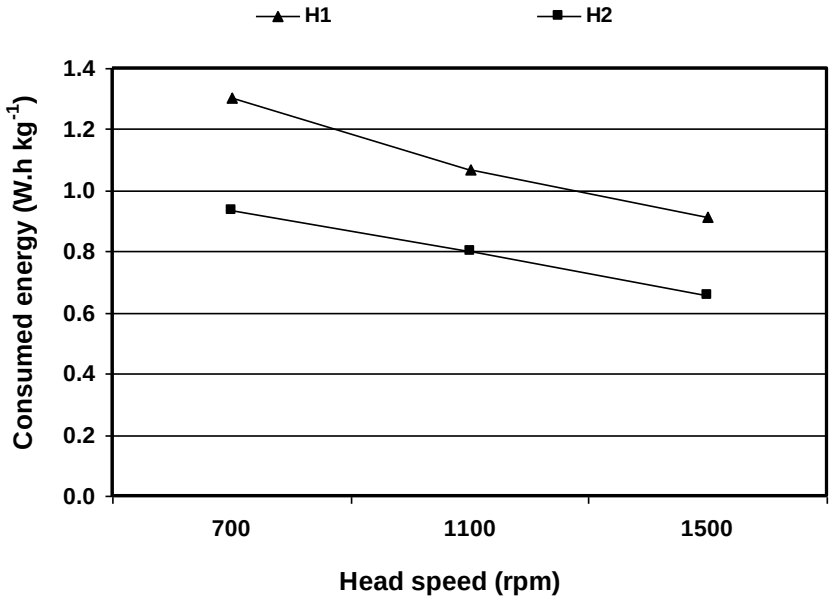


Fig. (8): Effect of speed and type of head on consumed energy.

3.7 Techno-economic feasibility

Fig. (9) shows the harvested olive fruits for one hour by the hand harvesting method and developed machine are 20 and 91.5 kg, and the harvesting costs are 0.94 and 0.26 L.E kg^{-1} (according to 2018 local conditions) respectively. Using the developed machine increased harvesting productivity to about 4.58 times and reduced the harvest cost to about 72.34% comparing with hand harvesting method. These findings prove the feasibility of the developed machine with productivity and cost.

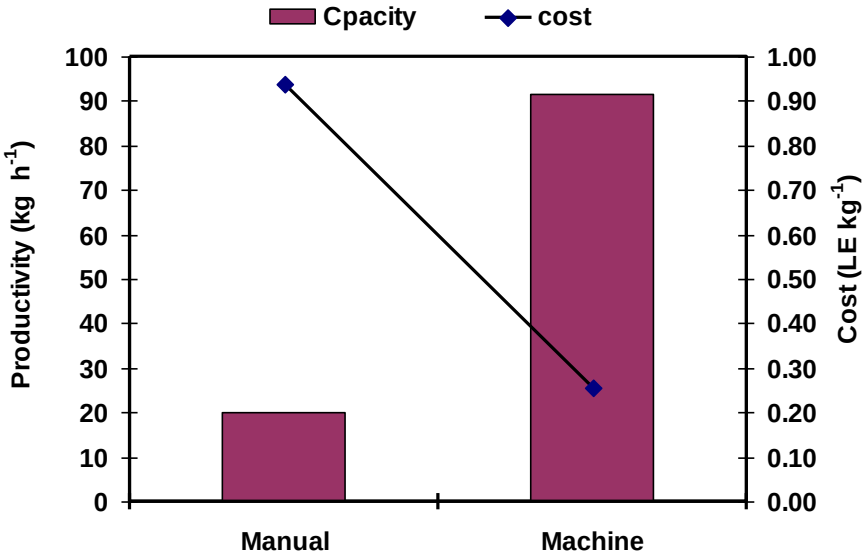


Fig. (9): Productivity and harvesting cost of the developed machine comparing with hand picking method.

CONCLUSIONS

The results of harvesting olive fruit by using developed hand- held machine can be summarized as follows:

1. Machine capacity increased with the increase of both head speed and stick length of the head.
2. Fruit removal percentage increased with the increase of both head speed and stick length of the head.
3. Fruit damage percentage increased with the increase both of head speed and stick length of the head.
4. Consumed energy decreased with the increase both of head speed and stick length of the head.
5. The most suitable machine perfect parameter conditions that realize the best harvesting condition were length 17 cm and head speed ranges from 1100 to 1500 rpm.

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الملخص العربى

تطوير آلة كهربائية محمولة لحصاد الزيتون

محمد محمود إبراهيم*

الزيتون أحد المحاصيل الهامة التي تزرع في منطقة حوض البحر المتوسط. تكمن الأهمية الإقتصادية للزيتون في القيمة المضافة للإنتاج الزراعي ومساهمته في الناتج القومى حيث تبلغ المساحة المنزرعة منه في مصر حوالي ٦٧٢٩٣ هكتار تنتج ما يقرب من ٦٩٤,٣ ألف طن. وتتمثل المشكلة الرئيسية للمحصول في عملية الحصاد (قطف الثمار)، حيث تتم عملية الحصاد يدوياً حيث تحتاج إلى عمالة كثيرة. ولذلك كان الهدف هو تصنيع آلة صغيرة محمولة تناسب الحيازات الصغيرة.

تم دراسة بعض الخصائص الطبيعية والميكانيكية لثمار الزيتون للإستعانة بها في تصميم الآلة: أبعاد الثمرة – كتلة الثمرة – حجم الثمرة – القوة اللازمة لفصل الثمرة ونسبة قوة الفصل إلى كتلة الثمرة.

تم دراسة القوى المؤثرة على ثمرة الزيتون اثناء الحصاد – ثم تم تصميم الآلة و حساب القدرة المتطلبة للالة للتشغيل.

الآلة المصنعة تتكون من: جهاز الحصاد – عصا التوجيه – مصدر القدرة وهو عبارة عن محرك كهربي صغير يعمل بالتيار المتغير ذو قدرة ٦٠ وات – مصدر الطاقة وهو مولد كهربائى ذو فولتية ٢٢٠ وقدرة كهربائية ٧٠٠ وات. تم تقييم أداء الآلة المصنعة باستخدام نوعين من أجهزة الحصاد (الأول له أذرع طولها ٦ سم والثاني له أذرع طولها ١٧ سم وذلك على ثلاث سرعات (٧٠٠ ، ١١٠٠، ١٥٠٠ لفة دقيقة$^{-1}$).

وكانت معايير التقييم كالتالى: الإنتاجية – نسبة الثمار المنفصلة - نسبة الضرر للثمار – الطاقة المستهلكة فى عملية الحصاد – تكاليف الحصاد.

وقد بينت الدراسة ما يلي:

١. تم إستنتاج علاقة بين كل من مربع السرعة الخطية الناتجة من دوران رأس الحصاد للالة بقيمة معامل (نسبة قوة فصل الثمرة إلى كتلة الثمرة ×طول عنق الثمرة)، حيث أن مربع السرعة يجب أن يكون أكبر من أو يساوى هذا المعامل لكى يتحقق فصل ثمرة الزيتون.

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٢. تم إستنتاج خريطة كنتورية لأداء الآلة يمكن التنبؤ بقيمة معامل (نسبة قوة فصل الثمرة إلى كتلة الثمرة ×طول عنق الثمرة) التى يمكن للآلة أن تحققه لحدوث فصل لثمرة الزيتون، وبالتالى يمكن التنبؤ بإمكانية تشغيل الآلة لاجراء الحصاد الميكانيكي لثمار الزيتون مع مختلف الأصناف.

٣. بلغت إنتاجية الآلة المصنعة حوالي ٤٥,٩ و ٦٤,٣ كجم ساعة$^{-1}$ عند التشغيل بجهاز الحصاد ذو الأذرع ٦ سم و ١٧ سم على التوالي وذلك عند السرعة الدورانية ٧٠٠ لفة دقيقة$^{-1}$. وعند زيادة السرعة إلى ١٥٠٠ لفة دقيقة$^{-1}$ كانت الإنتاجية حوالي ٦٥,٨ و ٩١,٥ كجم ساعة$^{-1}$ على التوالي.

٤. بلغت نسبة فصل الثمار للآلة المصنعة حوالي ٨٠,٤ و ٨٩,٧ % عند التشغيل بجهاز الحصاد ذو الأذرع ٦ سم و ١٧ سم على التوالي وذلك عند السرعة الدورانية ٧٠٠ لفة دقيقة$^{-1}$. وعند زيادة السرعة إلى ١٥٠٠ لفة دقيقة$^{-1}$ كانت نسبة فصل الثمار حوالي ٩١,٢ و ٩٧,٧ % على التوالي.

٥. بلغت نسبة الضرر الميكانيكي للثمار للآلة المصنعة حوالي ٤,٥ و ٥,٣ % عند التشغيل بجهاز الحصاد ذو الأذرع ٦ سم و ١٧ سم على التوالي وذلك عند السرعة الدورانية ٧٠٠ لفة دقيقة$^{-1}$. وعند زيادة السرعة إلى ١٥٠٠ لفة دقيقة$^{-1}$ وصلت نسبة الضرر الميكانيكي للثمار إلى حوالي ٥,١ و ٦,٢ % على التوالي.

٦. بلغت الطاقة المستهلكة لحصاد الثمار للآلة المصنعة حوالي ١,٣١ و ٠,٩٣ وات.ساعة كجم$^{-1}$ عند التشغيل بجهاز الحصاد ذو الأذرع ٦ سم و ١٧ سم على التوالي وذلك عند السرعة الدورانية ٧٠٠ لفة دقيقة$^{-1}$. وعند زيادة السرعة إلى ١٥٠٠ لفة دقيقة$^{-1}$ كانت الطاقة المستهلكة للثمار حوالي ٠,٩١ و ٠,٦٦ وات . ساعة كجم$^{-1}$ على التوالي.

٧. ينصح بإستخدام الآلة المطورة في عملية حصاد الزيتون بإستخدام جهاز الحصاد ذو الذراع ١٧ سم وذلك عند السرعات من ١١٠٠ إلى ١٥٠٠ لفة دقيقة$^{-1}$.

٨. بلغت تكاليف عملية الحصاد حوالي ٠,٢٦ جنيه كجم$^{-1}$ للحصاد الميكانيكي بإستخدام الآلة المصنعة في حين بلغت حوالي ٠,٩٤ جنيه كجم$^{-1}$ مع الحصاد اليدوي.