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International Journal of Agricultural Management and Development (IJAMAD)
Available online on: www.ijamad.iaurasht.ac.ir
ISSN: 2159-5852 (Print)
ISSN:2159-5860 (Online)

Techno-economic Efficiency of Trunk and Mechanical Harvest Aid Shakers for Harvesting Olive Fruits in Guilan Province, Iran

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Received: 20 December 2015,
Accepted: 04 July 2016

Abstract

The main concern of an olive grower is primarily to achieve more income and profits. A harvesting method having higher efficiency and better fruit and oil quality, but a higher operation cost leads to a lower benefit. A study was carried out to evaluate the techno-economic performances of Trunk Shaker (TS) and Mechanical Harvest Aid (MHA) shaker for harvesting the yellow and Manzanilla olive cultivars in Guilan province, Iran. A factorial experiment based on randomized complete block design was used in four treatments at three replicates. The percentage of harvested fruit, fruit harvest rate (kg h^{-1}), harvesting efficiency, leaf abscission, canned fruit acidity, and the percentage of bruised fruits, fruit tissue resistance were determined as the technical traits and benefit to cost ratio to evaluate the economic performance of experimental olive harvesting methods. The results showed that the TS with 60.6 had more harvesting percent of fruit than the MHA (24.1). Average harvesting time of a tree was recorded 10.7 minutes by TS that this was 8.2 minutes in MHA. The harvesting efficiency in TS method of Manzanilla variety was much more MHA method and yellow variety. The efficiency was 100.38 kg h^{-1} in TS that is more than in the method of MHA with 43.72 kg h^{-1}. Fruits harvested with TS, with an average of 1.07 Newton, had a higher firmness of the fruits in compared to MHA method. TS method with 1270 dollar per day had more benefit compared to MHA method with a profit of $606.

Keywords:
Canned olive, Mechanical olive harvest, Economic, Technical performance

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INTRODUCTION

The production and consumption of olive oil have an uptrend in Iran, so the area of cultivated olive orchards and olive oil increased to 115,464 hectares and 103,000 tons in 2012, respectively. There is such a situation in the world, so that the production of olive oil has increased from 2,713,000 tons to 3,321,000 tons in the five-year period (2008-2012). The production of canned olives in the world is reached from 2151000 to 2432000 tons in the same period (Ministry of Agriculture, 2012).

Harvesting is the final step in field production of an olive crop, but if done at the wrong time or in the wrong way it can markedly affect net return to the grower.

The olive harvest is expensive in terms of wages and adequate labor supply has created many problems (Zipori *et al*., 2014). Economic standpoint is that the maximum efficiency with minimal cost, so it is important to improve the olive harvest mechanization. Different methods of harvesting olives that is already used in olive producing areas of the world included the ground harvesting; timber, manual, shoulder, and mechanical harvesting. Harvesting method is a function of the amount of fruit, shape and form of the tree, garden area, land steep and labor costs (Castro-Garcia *et al*., 2009). The main purpose using this device, saving time and costs of harvesting and increase in profits. To facilitate and expedite the olive harvest, some efforts were begun to build machinery from early last century (Lamouria and Hartmann, 1955). The kind of variety is effective in fruit quality in a mechanization method, so Zipori *et al*. (2014) proved that the quality of canned varieties of Hoojiblanks, Surrey and Nebaly Mohsen was better than Manzanilla. For mechanized harvesting of olives using the TT, garden slope should be less than 20% (Gomez *et al*., 2008). The types of machines of olive harvesting in various size and functions have been designed. Two main methods include the use of pneumatic shoulders, and tree shakers.

The comparison between stem and canopy shakers in Spain showed that the fruit harvested efficiency was 85 and 75%, respectively in stem and canopy shakers, while this was up to 90% in combine harvesting (Castro-Garcia *et al*., 2009). A study of California showed the amount of harvesting (harvesting efficiency) at these methods respectively 39.8, 71.6 and 111.4 pounds (Vossen, 2006). A research of America on the mechanized harvesting efficiency of oil and canned olives showed that the efficiency of both devices (canopy and stem) was less than 80% (Ferguson *et al*., 2010). Castro-Garcia *et al.* (2009) in southern Spain found that the manual harvesting method enters the less damage to fruit variety Manzanilla and the efficiency is 93% but the harvesting amount was low (250-200 kg per person per day). Against, the harvesting efficiency of stem shaker about 80-85% but the harvesting amount was 1440 kg/day. In a study, Ravetti and Robb (2010) compared the performance of canopy shaker model Colossus and side-by-side shaker and found that the harvesting efficiency of these machines differentiates in terms of variety, yield and fruit maturity. The efficiency of canopy and side-by-side shakers was respectively 86-96 and 58-91%. The damage to branches was 1% in side-by-side shaker and 1.5-3.5% model Colossus.

The tree form and damage to tree is the major constraints in compatibility to mechanical harvesting. A study by Jimenez-Jimenes *et al.* (2013) in the use of stem shaker to harvest Manzanilla olives showed that the blue color in mechanical harvesting method is 12 times more than manual harvesting method. The reason of damage is due to friction of fruit to fruit and branches during tree shaking by the shaker. In fact, 60% of the damage to canned olives caused by these factors.

Now the olive harvest is done by hand involved problems such as labor supply (especially for large gardens) and lot of time in addition to labor costs. The harvesting costs of olive in Iran covers 40% total cost of production (Kermani and Pile Forush, 2010) that these problems will accelerate with regards to developmental program of Agriculture Ministry, Iran, for increasing olive production. The cost of manual harvesting of olive is computed 40% more than mechanized methods in developed countries due to the high cost of manual labor (Ferguson, 2010). The

quality of fruit and canned olive or obtained oil depends directly on the time and method of fruit harvesting, so when the fruit is harvested at appropriate time and method, canned and oil of olive will be obtained in a higher quality. Development of mechanized harvesting is a safe way to harvest inexpensive and healthy fruit, so to do a research study in the field have the special importance.

The purpose of an olive grower is primarily achievement to income and profits. A harvesting method having higher efficiency, fruit quality and oil but a higher cost is led to a lower benefit, that certainly it is not a proper option for oil growers. Therefore, to introduce an applicable method to the farmers, the cost of the system should be considered as the most important factor. In general, the following objectives are considered in this study:

1. Introducing the most appropriate method of canned olive harvest,
2. Evaluating the performance and cost of two mechanized methods in harvesting canned olive.

MATERIALS AND METHODS

Experimental design and treatments

This research was conducted in the Guilan Agro-industrial Complex, Guilan Province, Iran. The complex has 36º38' northern latitude and 49º31' eastern longitude with an elevation of 500 meters from the sea level with dry climate. This study was carried out at two phases of field trials and laboratory studies to evaluate two harvesting methods of Trunk Shaker (TS) and Mechanical Harvest Aid (MHA) shakers (Figure 1) on varieties of yellow and Manzanilla olives. A factorial experiment based on randomized complete block design was conducted in four treatments at three replicates. The area of olive orchards is 470 hectares and it is one of the largest integrated orchards of country. Trees are irrigated by an under pressure system (drip) and they have been planted in dimensions 8 × 6 meters.

For each plot, three rows and in every row, three trees 17 years old were selected. So each plot consisted of nine trees that the measurements and samples were taken from three middle of trees. After selecting trees, olive orchard was divided into blocks. The fruit color change was observed in our study in early October. Olive harvest in October was the third date. The measured traits were the percentage of harvested fruit, fruit harvest rate (kilograms per hour), leaf abscission, canned fruit acidity, and firmness of fruits and the percentage of bruised fruits.

Field measurements

During the olive harvest, fruits per plot in two methods, were collected and weighed. After the harvest, the fruit remaining on the trees by hand were harvested and weighed. Then the percentage of harvested fruits was calculated for each plot using Equation 1 (Sessiz and Ozcan, 2006):

$$P_r = W_r/(W_r + W_u)*100 \quad (1)$$

P_r: The percentage of harvested fruits
W_r: The weight of harvested fruits by machine
W_u: The weight of harvested fruits by hand

For each plot, the required time to harvest fruits were recorded by stopwatch and after that, all harvested fruits were weighed. Using the definition of the harvesting efficiency (Abdine

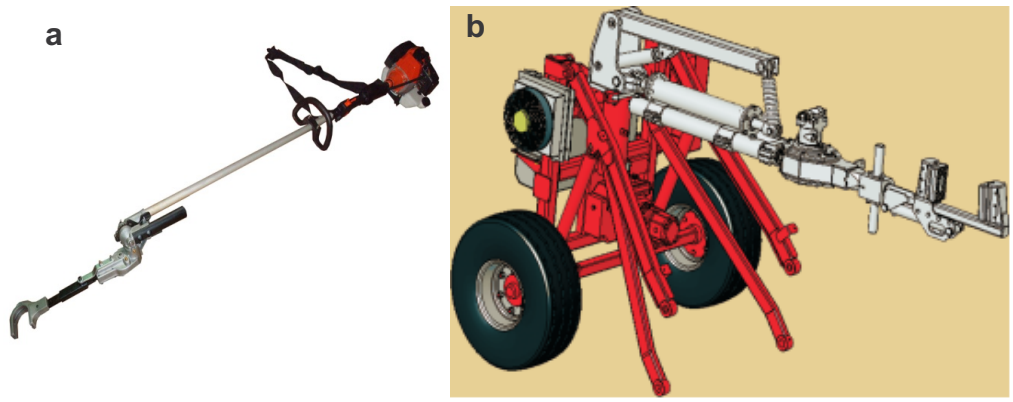

Figure 1: a: Mechanical Harvest Aid (MHA) shakers and b: Trunk Shaker (TS)

et al., 2006), that is the amount of olive harvested (kg) in one hour based on equation (2), it was calculated the efficiency of harvesting. Then, for each plot, harvesting efficiency was calculated:

$$HE = Harvested\ fruits(kg) / Time\ (hr) \quad (2)$$

Since the yield of every tree influenced by leaves numbers and leaf area index (Koochaki and Sarmadi, 2003), therefore the fallen leaves were collected and weighted. Thus, the required time to harvest fruits of every tree was calculated by stopwatch.

Experimental measurements

To determine the firmness, 10 olives were randomly selected from each plot and then the resistance of fruit tissue against pressure was measured in Newton (Nikkhah and Ganji Moghadam, 2003). To measure the resistance of olives, the needle half a millimeter in diameter were used. From each treatment, cannery solution was separately prepared by using caustic soda in the usual way. When ready to eat canned olives, and bitterness were taken, using pH meter canned solution acidity was measured for each treatment.

Economic analysis

To calculate the amount income of each treatment, using harvesting efficiency, the harvested fruit in one day were computed, and then, the value of canned olives was calculated. Income, including $18 for every kilogram of canned olives was obtained. The cost per treatment is the total labor costs, the cost of canned preparation and machine used in a day. A labor charge, $90 (wage worker at a day) was considered. The rent of machine was calculated by the constant and running cost of a car per day plus 15% profit (Yousefi *et al.,* 2013). About $0.5 estimated cost of canned olive per kilogram. To estimate the benefit of any treatment, income and expenses paid in each treatment was calculated. Net profit obtained from the difference between revenue and cost of treatment. The mean comparisons were analyzed by Least Significant Difference (LSD) in 5% level.

RESULTS AND DISCUSSION

Harvesting indices of fruits

The results of data analysis (Table 1) showed that the effect of harvesting method on the percentage of harvest, fruit acidity, fruit firmness and harvesting efficiency was significant. However, it was not significant on the harvest time. The variety and the interaction effect of harvesting method and variety were only significant on leaf falling percent.

Table 2 shows the effect of harvesting method, variety and its interaction effect on measured parameters. The results showed that the TS with 60.6 had more harvesting percent than the MHA (24.1). Yousefi *et al.* (2013) reported that the canned olive harvesting percent of yellow variety was 64.07% by TS which was significantly higher than the harvesting percent of MHA and manual and pneumatic shoulders. In a study conducted in California, USA, the percentage of harvested olive in both stem and branch shakers was measured less than 80% (Castro-Garcia *et al.,* 2009). Harvesting percent of yellow variety was much higher than the Manzanilla.

Table 1: The ANOVA results of the treatments effect on the measured indices

Variation resources	df	Mean Squared (MS)					
		Harvesting percent	Harvesting time	Leaf falling percent	Fruit acidity	Fruit firmness	Harvesting efficiency
A: Harvesting method	1	3999.3**	18.7ns	48.6**	0.69*	0.29*	9629.8**
B: Variety	1	0.11ns	18.0ns	3.8**	0.0007ns	0.04ns	2079.1ns
A×B	1	43.3ns	0.08ns	0.63*	0.007ns	0.006ns	47.0ns
Error	6	38.7	20.2	0.10	0.07	0.02	385.3
C.V. (%)		14.7	19.5	6.2	5.4	18.4	27.2

*p<0.05, **p<0.01, ns: not significant

Table 2: The effects of treatments on the measured indices of harvested olive fruits

Harvesting method	Harvesting percent	Harvesting time (minutes)	Falling leaf percent	Fruit acidity	Fruit firmness	Harvesting Efficiency (kg/hr)
TS	60.6[a]	10.7[a]	3.26[b]	5.28[a]	1.07[a]	100.4[a*]
MHA	24.1[b]	8.2[a]	7.29[a]	4.80[b]	0.76[b]	43.7b
Variety						
Manzanilla	16.63[a]	7.8[a]	9.43[a]	5.05[a]	0.97[a]	85.2[a]
Yellow	42.51[a]	10.7[a]	5.84[b]	5.04[a]	0.85[a]	58.8[a]
Harvesting method ×Variety						
TS and Manzanilla	58.6a[b]	9.3[bc]	2.93[b]	5.26[a]	0.80[a]	111.6[ab]
TS and Yellow	62.6a[b]	12.0[abc]	3.6[b]	5.31[a]	0.72[a]	89.2[ab]
MHA and Manzanilla	22.4b[c]	9.3[bc]	8.1[a]	4.78[a]	0.98[a]	28.6[bc]
MHA and Yellow	25.9b[c]	6.3[c]	6.5[ab]	4.83[a]	1.15[a]	58.9[bc]

*Values followed by the same letters in each row and column are not significantly different at the 0.05 level (least significant difference)

Harvesting time

Average harvesting time of a tree was recorded 10.7 minutes by TS that this was 8.2 minutes in MHA. In the Manzanilla, spent less time to harvest compared to yellow. Based on field views, the required time to harvest canned olive of a tree by hand was more than 100 minutes that this is 10 times more than spent time in TS and MHA. TS and MHA devices in studies Kermani and Pile Forush (2010), caused to reduce the total harvest (mechanical + traditional) of olive amounted 58.1and 56.98, respectively. Vossen (2006) in California, USA, the harvesting time for a tree calculated 20'15", 11'20" and 7'10" respectively in manual method, pneumatic and MHA. The lower time in harvesting a tree than field view can be due to variety and kind of pruning that worker can fast and easier harvest fruits.

Harvesting efficiency

The results in Table 2 show that the harvesting efficiency in TS method of Manzanilla variety was much more MHA method and yellow variety. Most efficiency was observed in TS method of Manzanilla variety. The efficiency is 100.38 kg per hour in TS that is more than in the method of MHA with 43.72 kg/hr. In other words, the efficiency of TS 2.29 times more than MHA. Vossen (2006) reported the efficiency of harvesting 39.8, 71.6 and 111.4 pound by using the hands, pneumatic shoulders and MHA, respectively. In Yousefi *et al*. (2013) study, efficiency of harvesting of the canned olive variety yellow was less than MHA method. By comparing the harvest efficiency of oil and canned olive, comes to the conclusion that the TS and MHA devices in the oil olive harvest was higher canned olive.

The falling leaf percent

The results in Table 2, the leaf abscission of yellow variety in MHA method by mean 8.08, significantly higher than other treatments. Kermani and Plie Forush (2010) reported that the falling leaf in oil olive was more than yellow variety, therefore it can be concluded that the determination of the percentage of leaf abscission is crucial.

Acidity and fruit tissue firmness

Results for acidity (Table 2) showed that the solution canned fruits harvested by TS (5.28) had the acidity higher than in the MHA method. Fruits harvested with TS, with an average of 1.07 Newton, had a higher firmness of the fruits in compared to MHA method. If olive fruits during harvest injured, their tissues are shattered and firmness decreases, it can be concluded that the fruits harvested by MHA method caused to the more damage.

Economic analysis

The final decision an olive grower to choose a harvesting method depends on the amount of profit and return on investment. Accordingly,

Table 3: The effect of treatments on the economical indices

Harvesting method	Income (US Dollar/day)	Cost (US Dollar/day)	Profit (US Dollar)
TS	1270	131	1400
MHA	606	39	610
Variety			
Manzanilla	85	1189	1104
Yellow	85	821	737
Harvesting method variety			
TS and Manzanilla	1425	131	1556
TS and Yellow	1113	131	1244
MHA and Manzanilla	360	38	399
MHA and Yellow	591	38	821

Table 4: The benefit to cost ratio for different treatments of olive harvesting (value to dollar)

Row	Treatments	Total cost	Total profit	Profit to cost ratio
1	Harvesting Yellow olive variety by Trunk Shaker	130.7	43423	8.51
2	Harvesting Manzanilla olive variety by Trunk Shaker	130.7	55589	10.89
3	Harvesting Yellow olive variety by Mechanical Harvest Aid	3.8	15397	102.6
4	Harvesting Manzanilla olive variety by Mechanical Harvest Aid	3.8	31873	212.5

one of the ways of planting and harvesting machinery in their acceptance by olive growers, reduce costs and increase profits at the harvesting stage. To estimate the amount of income, total income and expenses for each treatment was calculated on a daily basis. Costs include rent a car, labor and cost of making canned fruits olive per treatment in a day. Income the value of canned olives harvested in one day in each treatment was calculated. Table 3 shows the effect of treatment on costs, revenues and profits. TS method with $1270 of a day had more benefit compared to MHA method with a profit of $606. In treatments of Manzanilla variety, the profits, was more than in the yellow variety. This is due to the higher yield of Manzanilla variety.

The benefit to cost ratio of experimental treatments are shown in Table 4. The benefit to cost ratio of harvesting the Manzanilla olive cultivar by MHA was highest among treatments. At this treatment for a unit spending cost, 212.48 units benefit is achieved which when compared with other treatments, it is considerable value. For a unit of money spent on harvesting the yellow variety with TS, only 8.51 units profit was

Figure 2: The damage entered to branch of tree by using TS shaker

Figure 3: The damage entered to branch of tree by using MHA shaker

achieved. The benefit to cost ratios of treatments with harvesting by TS was low due to the costs incurred to purchase the device. Manzanilla treatments had the benefit to cost ratio also higher than yellow variety. Because of this is the higher yield the Manzanilla than the yellow.

Damage of harvesting devices to stem and branch of trees

TS and MHA devices taking branches of trees and their shaking caused to fall fruits. At the junction of the devices maxillary to branches, there is a cushion that reduces the damage from the jaws of the tree. However, according to field observations, both devices were causing rupture and decay bark that the Figures 2 and 3 show an example of this type of injury. TS shaker tend to more damaging to the tree due to the larger jaw.

CONCLUSION AND RECOMMENDATION

TS method had the higher efficiency and percentage of harvesting than MHA method. The harvesting of yellow variety by MHA method tends to less falling leaves in compared with other treatments. Damage to the olive fruits in MHA method was more than TS and their firmness was lower. The junction of MHA device to branches caused to more damage than TS method. The Manzanilla as a foreign variety and yellow as a local variety taking consideration into time, percentage and efficiency of harvesting, acidity, firmness and profit had not a significant difference. The profit obtained from harvesting by TS in a day was two times more than MHA shaker. To harvest yellow variety by TS shaker had the lowest profit to cost ratio due to high cost of rent of TS device. Pay attention to harvest canned olive, the percentage of harvesting is very low in MHA shaker and TS shaker only harvested 60% of fruits, therefore both methods are not appropriate to harvest canned olive.

With regard to the equal efficiency and percentage of harvesting in both methods (TS and MHA) and this point that the olive oil plays an important role in the health of society, and also the increase in olive oil production is a final goal of olive cultivation development in country, it is suggested that the traditional orchards develops to the production of olive oil until the harvesting cost reduces by these devices. Of course to prevent disadvantage of growers due to the production oil instead of canned olive, officials should be provided the possibility production of high quality oil, its export and the supervision on the oil import.

ACKNOWLEDGEMENT

The authors would like to thank Islamic Azad University, Rasht Branch, particularly Mr Haghighat and Mrs Hedayati due to their aid and facilities.

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How to cite this article:
Mohammadi Torkashvand, A., & Nayeri, F. (2016). Techno-economic efficiency of trunk and mechanical harvest aid shakers for harvesting olive fruits in Guilan province, Iran. *International Journal of Agricultural Management and Development, 6(3), 273-280.*

URL: http://ijamad.iaurasht.ac.ir/article_524104_1d1cc95cc22268637afc9a09637a01ab.pdf