Table olive response to harvesting by trunk shaker


Abstract

Table olives used to be harvested manually, but lately, due to the little benefit provided by this crop, farmers have started to employ mechanized methods to harvest table olives in order to reduce total crop costs. Trunk shakers has two main problems when they are used to collect it, the low fruit detached percentage, and fruit bruising. In 2013 harvest season, five different farms and seven different trunk shakers were studied to determine their adaptation and their performance of the harvesting operation. In all farms table olives (Olea europaea L. pomiformis) ‘Manzanilla’ cultivar were grown. Six trees were studied per trunk shaker, measuring fruit detached percentage, debris produced by trunk shaking and fruit exhausting operation, Fruit detachment force, mean fruit weight and tree geometrical characteristics. Three triaxial piezoelectric accelerometers (PCB, 356A02) located at trunk shaker near hydraulic engine, trunk near the shaking device and at one representative fruit bearing branch of the canopy to characterize de vibration path along the tree structure. Signals were stored and analyzed by a dynamical signal analyzer (OROS, 25-PC pack II). Two vibration time treatments were applied to three trees per machine, 5 + 5 + 5 s and 7.5 + 7.5 s. Whole vibration time was maintained constant in order to avoid its influence on measured parameters. Fruit detached percentage varied from 87 to 56 %. Produced debris fluctuated between 1.34 and 4.8 kg/100 kg detached fruit during trunk shaking. Harvesting process generated 24.15 s⁻¹ vibration frequency by mean, varying between 17.3 and 31.5 s⁻¹. Mean measured acceleration was 199.2 m s⁻² in the shaking device, 167.8 m s⁻² in the tree trunk and 257.7 m s⁻² in the fruit bearing branches. Results showed that vibration was reduced when it moves from trunk shaker to tree trunk and it was amplified when it pass through tree structure to arrive fruit bearing branches. Detached fruit had significant correlation with acceleration in fruit bearing branches, therefore the main objective for farmers should be to improve tree structure to facilitate vibration travel from machine to fruits. Vibration frequency were kept along the vibration path, so, acceleration varies depending on displacements, for this reason acceleration used to be amplified in fruit bearing branches. Vibration transmission ratio was 86 % between the machine and trunk and 172 % between trunk and branches. Two time vibration treatments showed significant differences. 7.5 + 7.5 s provided 68.5 % of detached fruit by mean, and 5 + 5 + 5 s treatment detached 75.7 % of total tree production.

Keywords: acceleration, frequency, detached fruit, debris.

1 Introduction

Table olives are the second main product provided by olive tree. The IOOC foresights for 2013/14 harvesting season are that Mediterranean basin will produce 2,222,200 t of table olives, while other countries will obtain only 352,000 t. Spain will harvest the highest table olives quantity, 513,100 t, about 20 % of table olives world production (IOOC, 2014). Howev-
er, Obtained data from table olives processing industry showed that in 2013 harvesting season Spain have produced 571,220 t (AICA, 2014).

The way and time for harvesting are conditioned by olive transforming process (Garrido-Fernández et al., 1997). Cv. ‘Manzanilla’ is the widespread cultivar in Spain and all over de world (Barranco, Fernandez-Escobar, & Rallo, 2010). Table olives used to be harvested when they are not completely ripen, in this fruit stage, fruit detachment force was rather high (Kouraba et al., 2004). This type of fruits presents high susceptibility to bruise (Segovia-Bravo García-García, López-López, & Garrido-Fernández, 2011). Due to these reasons, table olives are traditionally harvested by hand (Rejano, Montano, Casado, Sánchez, & De Castro, 2010), however, trunk shaker harvesting devices are widespread in oil olives (Gil-Ribes, Blanco-Roldán, & Castro-García, 2009). On the one hand, trunk shaker introduction for table olives harvesting requires that two main problems are solved: It is necessary to increasing harvesting efficiency rates, and to reduce fruit bruising percentages (Ferguson et al., 2010). On the other hand, it can improve harvesting field capacity until 0.12 – 0.20 ha h⁻¹ provided by tractor hitched trunk shaker, or 0.25 – 0.30 ha h⁻¹ provided by self propelled trunk shakers (Agüera-Vega et al., 2013). In addition, it would not rely on high hand labor requirements, that restrict the time that harvesting can be carrying out, and increasing the duration of the harvesting period. Therefore the risk of overripe fruits, or rains threaten that delay fruit harvesting.

Trunk shaker was introduced some decades ago, it has been used to harvest traditional olive orchards whose tree structure and orchard design were not adapted to efficient mechanical harvesting. It is necessary that orchard design and tree architecture will adapt to the chosen mechanical harvesting system for each exploitation (Castillo-Ruiz et al., 2013). Tree training was a main role for allow acceleration transmission from the shaker head to the fruit bearing branches, travelling along the tree structure. An adequate tree training that facilitates acceleration transmission, improves mechanical harvesting performance (Vieri, & Sarri, 2010), considering that majority of plantations are adapted to manual harvesting, and fruit production is located at the end of hanging and flexible branches, which act as cushions for vibration transmission. Also, trunk shaker performance parameters could be adapted to harvest table olives, now that, high fruit detached percentages can be reached by means a certain combination between frequency and amplitude (Torregrosa, Cuenca, & Ortiz, 2012), Canopy damages, known as debris, must be avoided during harvesting operation. The detachment of leaves, stems and branches has implications for the productive capacity of the trees (Wiesman, 2009). It also facilitates the transmission of disease and increases the cost of transport and processing of the product (Spann & Danyluk, 2010). For oil olives, trunk shaker debris production is similar to hand held harvesting equipment, such as branch shaker or shaker comb, and lower than damaged produces by harvesting with long poles (Sola-Guirado et al., 2014). Harvesting using long poles are not feasible for table olives due to the high level of fruit bruising that it produces. In this case, hand harvesting generates less debris than any mechanical or semi-mechanical harvesting system.

The aim of this research is to determine the feasibility of mechanical harvesting by trunk shaker to harvest olives for Spanish-style green table olives processing. It also is studied the vibration process to register accelerations along the tree structure, and the optimal vibration pattern to increase harvesting efficiency.

2 Materials and methods

In 2013 harvest season five farms located southern Spain in Seville, Cordoba and Badajoz provinces. In all farms table olives (Olea europaea L. pomiformis) ‘Manzanilla’ cultivar were grown (Figure 1). Trials were carried out from 24/09/2013 to 17/10/2013, trying to choose the optimal ripeness fruit stage to harvest table olives for Spanish-style green table olives preparation (Sánchez, García, & Rejano, 2006). All farms was composed by high density olive orchards one trunk trained, therefore, they are adapted to mechanical harvesting using trunk shakers. Seven machines were studied to determine their working parametters, accelerations and harvesting efficiency.
Seven trunk shakers mounted on seven different tractors were used to harvest fruits (Table 1). The aim to use this variety of machines is to represent faithfully the real possibilities of introduce a mechanical harvesting system based on trunk shakers for table olives. All tractors were tested at 30 engine cycles s\(^{-1}\), and clamp pressure were keep constant between trees and machines.

Table 1: Farms, tractors and trunk shakers used to perform the tests.

<table>
<thead>
<tr>
<th>Farm</th>
<th>Trunk shaker</th>
<th>Tractor</th>
<th>Tractor power (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>La Reunión - Aceituna Guadalquivir</td>
<td>Topavi, vibrador linea BV</td>
<td>John Deere, 6800</td>
<td>88.2</td>
</tr>
<tr>
<td>(Morón de la Frontera, Seville)</td>
<td>Arcusin, Autopick GT</td>
<td>Case, III MXM 120</td>
<td>88.2</td>
</tr>
<tr>
<td>Los Ángeles de Santa Ana</td>
<td>Agromelca, VM 100</td>
<td>John Deere, 6520</td>
<td>91.8</td>
</tr>
<tr>
<td>(Alcalá de Guadaira, Seville)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuenreal Alto (Almodóvar del Río,</td>
<td>Arcusin, Autopick GT</td>
<td>New Holland, TN 95 FA</td>
<td>69.8</td>
</tr>
<tr>
<td>Cordoba)</td>
<td>Arcusin, Autopick GT*</td>
<td>New Holland, CM 93</td>
<td>69.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Las Valdivias (Posadas)</td>
<td>Arcusín Autopick GT</td>
<td>New Holland, TL 100</td>
<td>73.5</td>
</tr>
<tr>
<td>Los Juncales (Solana de los barros,</td>
<td>Pellenc, FB 65</td>
<td>Deutz Fähr, Agrotron</td>
<td>102.9</td>
</tr>
<tr>
<td>Badajoz)</td>
<td></td>
<td>130</td>
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</tbody>
</table>

Six trees were harvested only using the trunk shaker, without operators that beat the canopy trees with long poles. Three triaxial piezoelectric accelerometers (PCB, 356A02) were located at trunk shaker near hydraulic engine, trunk near the shaking jaws and at one representative fruit bearing branch of the canopy to characterize vibration path along the tree structure. Signals were stored and analyzed by a dynamical signal analyzer (OROS, 25-PC pack II) (Figure 2). Once the tree were harvested, remained fruit on the canopy was exhausted manually to determined harvesting efficiency rate.
Two shaking treatments were applied in each farm. All trees in each farm were shaked during 15 s, the half of them giving a $5 + 5 + 5$ s vibration, and the others giving $7.5 + 7.5$ s vibration. Whole vibration time was maintained constant in order to avoid its influence on measured parameters.

3 Results

Fruit detached percentage in all farms varied from 87 to 56 % depending on different parameters such as trunk shaker brand and model, tree load or tree structure (Figure 3). The last one is the most influent parameter, considering that farms 1 and 2 have the most adequate tree structure for trunk shaking, with vertical and rigid structure. In addition, farms 6 and 7 ahve trees with many hanging branches and leaning trunks that dificulted trunk shaker harvesting performance. Produced debris fluctuated between 1.34 and 4.8 kg/100 kg detached fruit during trunk shaking.

Mean vibration frequency was 24.15 s$^{-1}$, varying between 17.3 and 31.5 s$^{-1}$. Mean measured acceleration was 199.2 m s$^{-2}$ in the shaking head, 167.8 m s$^{-2}$ in the tree trunk and 257.7 m s$^{-2}$ in the fruit bearing branches. Results showed that acceleration was multiplied by 0.86 when it moves from trunk shaker to tree trunk and it was amplified by 1.72 when it pass through tree structure to fruit bearing branches. Acceleration was multiplied by 1.36 during its travel from the shaking head to the fruit bearing branches, therefore, fruit detachment requires more acceleration than trunk shaker is capable to generate. Showed results agree with Du, cheng, Zhang, Scharf, & whithig, (2012), who describes how the acceleration is amplified along the tree structure.

Shaker head acceleration has strongly related to shaking frequency (Figure 4), in other words, shaking head displacement was independent from the machine and the tree.
Furthermore, vibration frequency varied depending on tree impedance, a good way to estimate this impedance is to measure canopy volume and fruit load.

Figure 4: Linear regression between resultant acceleration and frequency in the shaking head.

Detached fruit had significant correlation with acceleration in fruit bearing branches, therefore the main objective for farmers should be to improve tree structure to facilitate vibration travel from machine to fruits. Besides, they have to select the trunk shaker which can generate an adequate vibration to achieve high harvesting efficiency values. Vibration frequency were kept along the vibration path, so, acceleration varies depending on displacements, for this reason acceleration used to be amplified in fruit bearing branches. Other authors described that fruit detachment process is influenced by tree height, pendulous apical bearing habit, fruit location distance from the trunk and fruit weight (Ferguson et al., 2010) and variety (Antognozi, Cartechini, Tombesi, & Proietti, 1989). Fruit detachment force influence on fruit detachment process, but it cannot be used as the only indicator to describe it (Farinelli, Tombesi, Famiani, & Tombesi, 2012).

Figure 5: Linear regression between harvesting efficiency and fruit bearing branches resultant acceleration.
Two vibration patterns treatments showed significant differences. 7.5 + 7.5 s provided 68.5 % of detached fruit, and 5 + 5 + 5 s treatment detached 75.7 % of total tree production (Table 2). Therefore, it was advisable for table olive farmers to employ a short time and more repetitions vibration pattern that a long time and less repetition vibration pattern, above all, when both patterns are equal time consuming, and any or them reduces potential field capacity.

Table 2: Harvesting efficiency mean values obtained from all farms and tested machines. Different letters show significant differences between vibration patterns treatments according to Student’s T test.

<table>
<thead>
<tr>
<th>Vibration pattern (s)</th>
<th>Harvesting efficiency (%)</th>
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<tbody>
<tr>
<td>5+5+5</td>
<td>75.70 ± 12.10 b</td>
</tr>
<tr>
<td>7.5+7.5</td>
<td>68.48 ± 12.04 a</td>
</tr>
</tbody>
</table>

4 Conclusions

Mechanised table olives harvesting by using trunk shaker is feasible for Spanish-style green table olives preparation. It still provides low harvesting efficiency rates, but it can be used along long poles harvesting, or shaker combs, and that process can be improved by adapting olive tree structure to trunk shaker. Higher frequencies showed higher trunk accelerations, within the tested gap, and tree impedance determines vibration frequency. Harvesting efficiency can be predicted by fruit bearing branches acceleration, therefore, farmers should adapt tree structure to achieve an adequate vibration transmission. Vibration patterns that use more and shorter shakings, provided better results than the other ones that apply less and longer shakings. All of that keep the same vibration time.

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6 References


