Evaluation of a Citrus Mobile PlatformUusing a Wireless Impact Recording Device

Gyomar González[a], **Patricia Chueca**[a], **Coral Ortiz**[b *]

[a] Centro de Agroingeniería. Instituto Valenciano de Investigaciones Agrarias (IVIA), Ctra. CV- 315, km. 10. 46113 Moncada (Valencia), Spain

[b] Dpto. Ingeniería Rural y Agroalimentaria, Universitat Politècnica de València, Camino de Vera s/n, 46022 Valencia, Spain

* Corresponding author. Email: cortiz@dmta.upv.es

Abstract

Manual citrus harvesting is an expensive operation that represents between 25-40% of the total production costs. A mobile platform prototype to assist in the harvesting of citrus fruits designed by the IVIA (Spain) has been tested in order to reduce fruit damages. The mobile platform is fitted with conveyor systems. The multilevel platform can accommodate 4 to 8 workers who pick the fruit and place it on a conveyor belt. The picked fruit is transported to a central conveyor belt on which the fruit is transported to the in-line sorting system that classifies the fruit in two categories using a computer vision system and directs the fruit to one of the two different bin-fillers. During this process the fruits are subjected to mechanical stress causing physical injuries, including skin punctures, pulp and cell rupture. An impact recording device was used to evaluate damage produced to citrus fruits. The critical points at which damage occurs were determined, and the damage levels assessed. The highest damage level was produced from the bin-fillers to the bins. Seven different shocking absorbing materials were tested in order to reduce fruit damage. Five of the seven tested materials were capable to reduce the recorded impact.

Keywords: mechanical harvest, fruit damage, absorbing materials, instrumented spheres

1. Introduction

Spain is the first World's exporter of citrus for fresh market. In current Spanish fresh citrus orchards, fruits are manually harvested, then loaded in boxes and transported to a packing house, where boxes are unloaded, cleaned and fruit are pre-sorted. Manual citrus harvesting represents up to 50 % of current final production costs (Mateu et al., 2018), becoming 10 times higher in Spain than in many competitor countries (Juste et al., 2000). Mechanization of harvest would increase labor productivity and thus result in greater profits for agricultural entrepreneurs.

The system to be used for harvesting the fruit depends largely on what the fruit is going to be used for. Fruit destined to the processing industry could be mechanically harvested because certain types of damage on the peel of the fruit are acceptable. In contrast, fruit destined to be eaten fresh cannot have any kind of damage, whether internal or external.

Between different solutions for citrus mechanical harvesting, platforms seem to be the most adequate for fresh fruit due to its careful fruit management compared with the rest of solutions based on shaker systems. These machines are generally self-propelled and facilitate access to all parts of the tree for the pickers, so that they are only engaged in collecting the fruits and placing them directly in a conveyor belt or a field bag. These machines are being used in other crops like apple and pears grown in trellis systems. The company Argilés Disseny i Fabricació and IVIA have developed a platform machine for harvesting citrus, that is also capable of in-field sorting the harvested fruit into two different classes based on weight, using an electronic weighing system based on load cells, or on colour, using a machine vision system (Gutierrez et al., 2012).

The mechanical damages that occur in the fruits are a consequence of the combination of two main factors: the physical properties of the fruit and the damage inflicted on it during its harvesting and handling (Hernández, 2000). For citrus fruits, these injuries can be due to impact, compression or friction, being the damages by impact and compression undetectable in many occasions through an external observation. There are two alternatives for measuring citrus fruit impact, one is sampling fruit by measuring bruising and physical damage after harvest and the other is using instrumentation (Bollen, 2006). This instrumentation is based on electronic sensors (wireless impact recording device) that capture both the moment and the intensity of the dynamic loads suffered. With them, it is possible to evaluate any process and locate in it the points where the fruits are exposed to impacts, compressions and other situations of mechanical stress (Tennes et al., 1991).

This work objective was to evaluate the mechanical damage to citrus fruits in a part of the process carried out in the mobile platform prototype. After observing where the impacts of greater intensity were produced, seven materials were evaluated in order to assess their shock absorbing capacity.

2. Materials and Methods

Description of the harvest platform prototype

The mobile platform has three levels of fruit discharge: ground level (level 1), a first intermediate height on the platform (level 2) and a second height above the platform (level 3). It has a capacity for 4 to 8 operators positioned on the platform and between 4-6 workers at ground level.

Operators located in level 1 directly drop the fruit to the hopper. Operators of levels 2 and 3 drop the fruit to conveyor belts, where it is directed to the hopper. From this, the fruit is lifted by a conveyor belt with rubber fingers to the top of the platform where the classification system is located. In the upper zone the fruits are singled out into 4 lines or channels (Figure 1) and transported by rollers to the zone of classification by computer vision that classifies the fruit into two categories. In the in-line sorting system, the fruits are classified according to commercial caliber distributing the fruit in different bin-fillers (Figure 2). The internal bin is used for the low quality fruit (or non-commercial fruit) and the external one for the high quality fruit (or commercial fruit).

The prototype includes a trailer where the empty bin-fillers are stored to load them on the platform when needed and also facilitates the unloading of full bin-fillers in the field.

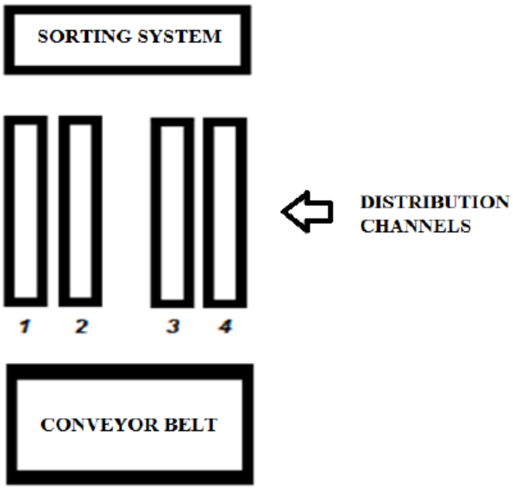

Figure 1. Outline of the top of the mobile platform.

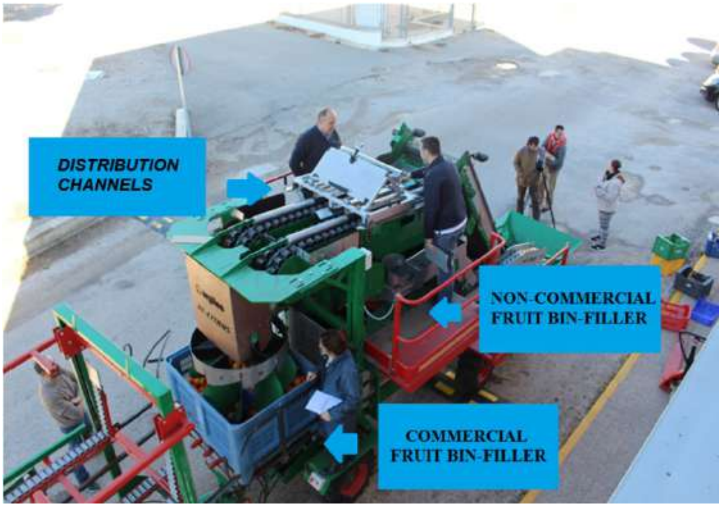

Figure 2. Harvest platform prototype.

Evaluation of impacts in the classification process in the prototype

A trial was carried out to evaluate the critical points during the classification process in the prototype which include the passage of fruit through the 4 conveyor channels of vision system and its destination to one of the two bin-fillers (internal and external). For that, a wireless impact recording device (IRD) (Tuberlog PTR 200, www.martinlishman.com) was used to measure the acceleration impacts. The IRD has an impact range between 30 and

500 G. The trial consisted in passing the IRD through each of the four channels at uniform advance speed of the conveyor belts established at 0.356 m s^{-1}. The caliber was set to establish where the fruit should be deposited forcing the evaluation of the two drop towards the bin-fillers. Three experimental repetitions were carried out per channel (4) and bin-filler (2).

The analysis of data consists of comparing the values of the impact acceleration obtained in the different repetitions for each channel and bin as a function of time. For this comparison, these impacts were displayed in graphs and the time corresponding to the highest impact acceleration value was taken as reference (in all cases this impact corresponds to the drop impact to the bin). This value was set as the origin of coordinates. The points to the right of the y-axis correspond to rebounds after the drop impact while the points to the left of the Y-axis correspond to the impacts originated during the process evaluated in the machine before the drop impact.

Evaluation of impact reducing capacity of different materials

A trial was carried out to evaluate the impact reducing capacity of seven different shocking absorbing materials (Figure 3) which could be used in the harvest platform to reduce the impacts observed in the previous section. The trial consisted of dropping the IRD described above at uniform advance speed (0.356 m s^{-1}) in the conveyor belt located before the fruit hopper and evaluate the impact over the different materials placed in the metallic system, that is between the conveyor belt and the fruit hopper, with a fall of 20 cm with respect to the conveyor belt (Figure 4). Ten sets of ten repetitions were carried out per material, with a total of 80 tests (70 with materials and 10 without material).

Material 1
Density: 46.36 Kg m^{-3}
Thickness: 41 mm

Material 2
Density: 26.74 Kg m^{-3}
Thickness: 43 mm

Material 3
Density: 15.56 Kg m^{-3}
Thickness: 23.25 mm

Material 4
Density: 23.37 Kg m^{-3}
Thickness: 10 mm

Material 5
Density: 16.44 Kg m^{-3}
Thickness: 9 mm

Material 6
Density: 18.26 Kg m^{-3}
Thickness: 18 mm

Material 7
Density: 146.87 Kg m^{-3}
Thickness: 3.10 mm

Figure 3. Materials.

Figure 4. Conveyor belt and metallic system placed before the fruit hopper in the prototype.

Because some impact measures with the IRD were lower than the minimum value range of the sensor (30G), the percentages of impact data lower than 30 G and higher than 30 G for each material were calculated. Later, data (higher than 30G) comparing the drop impact between materials were analyzed using one-way analysis of variance (ANOVA) at $P<0.05$. The least significant difference (LSD) multiple range test was used for mean separation at $P<0.05$. Before ANOVA, homocedastiticity and normal distribution of residuals were tested. Although the data were not follow these both hypothesis because of ANOVA results were the same that the obtained with the non-parametric Kruskal-Wallis test, the results of ANOVA were considered valid due to the robustness of the ANOVA (Statgraphics Centurion XVII).

3. Results and Discussion

Evaluation of impacts in the classification process in the prototype

Clear differences were found between the impacts registered from the two different bins (Figure 5).

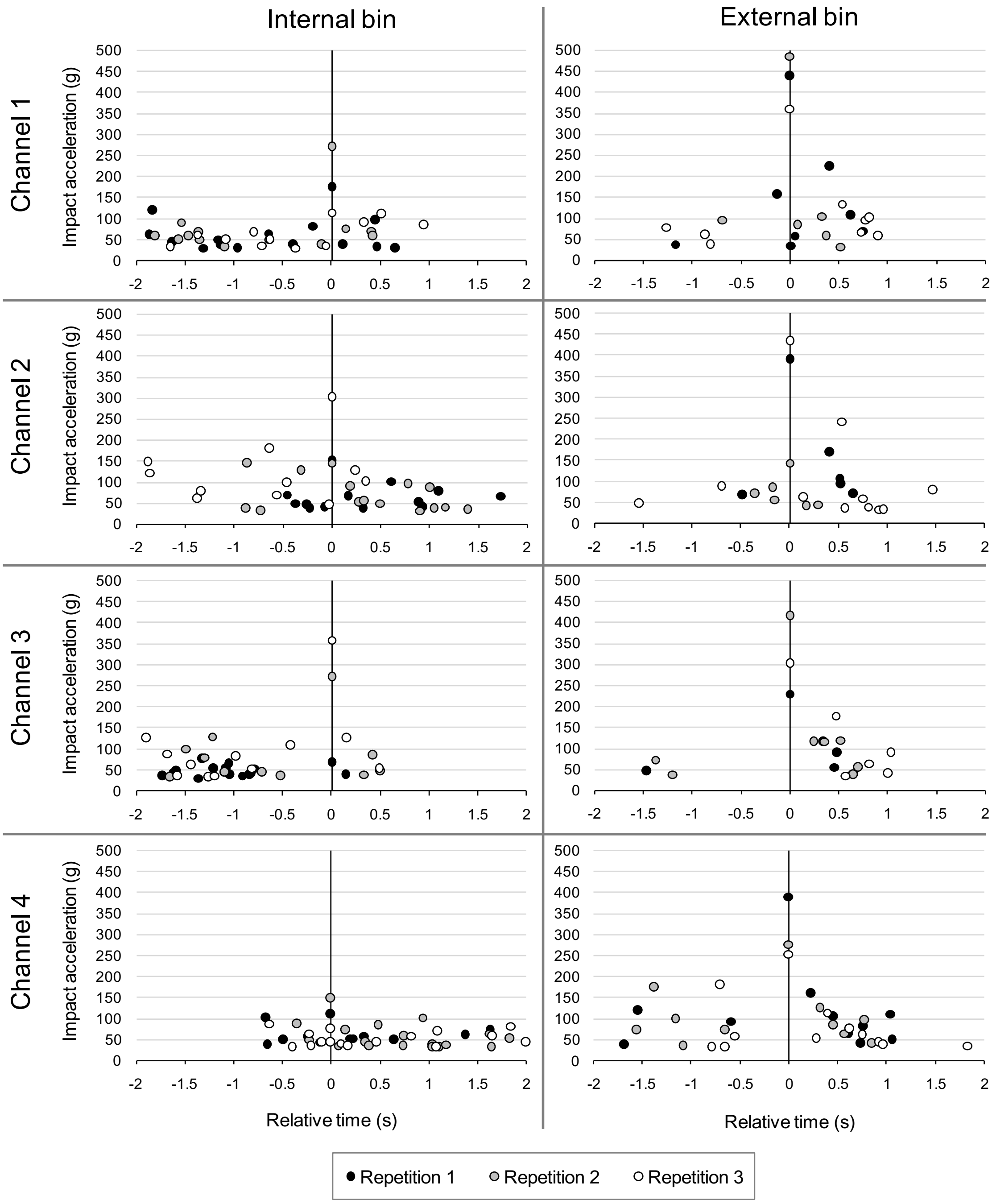

Figure 5. Impacts registered according to the bin and the channel. The highest impact acceleration (drop impact to the bin) value was taken as reference. The points to the right of the y-axis correspond to rebounds after the drop impact while the points to the left of the Y-axis correspond to the impacts before the drop impact.

In the external bin (except the channel 4):

- Few low impacts (from one to three) were registered before the drop impact, with values under 100G.
- A very high drop impact was registered, between 300 and 500 G.
- High impact rebounds were produced, in some cases around 200G.

In the internal bin (except channel 4):

- Several medium impacts (between 100 and 200 G) were found before the drop impact,
- A high drop impact was registered, between 150 and 300 G,
- Low impacts rebounds were produced after the dumping.

No clear differences were found between the impacts recorded in the different channels, except channel 4.

The impacts registered using channel 4 and the external bin before the drop were more numerous and considerably higher (nearly 200 G in some cases) than the ones registered using the other channels. The drop impact registered using the channel 4 was considerably lower (lower than 150 G in all the cases) than the ones registered using the other channels.

Evaluation of impact reducing capacity of different materials

Based on previous studies with potato harvesters using a similar wireless impact recording device, the maximum impact value that does not produce damage is 30G (Bentini et al., 2006). In citrus, according Miller and Wagner (1991), the value considered is a little bit higher 40G. Anyway, since the lower threshold of IRD is at 30G, and to be in the side of security, this value was considered as the lower threshold for our test.

Table 3. Percentage of impact data lower and higher that 30G for each material the reference value that not produces impact damage.

Material	% of data according to impact acceleration value (g)	
	<30	>30
0*	0	100
1	100	0
2	100	0
3	100	0
4	0	100
5	0	100
6	22.55	77.45
7	0	100

* Material was designated to the metallic system without shocking absorbing material.

Materials 1, 2 and 3 were the most shocking absorbing materials because all the impacts were lower than 30G. The following absorbing material was 6 because 22.55% of impact data were lower than 30G while the rest of materials presented all impact values higher that 30 G (

Table 3). In the statistical analysis of the data comparing the impact higher than 30G for the five remaining materials was observed that there was a statistically significant difference in the mean of impact acceleration (g) between the different materials (F = 141.69; df = 4, 509; P <0) (Figure 6).

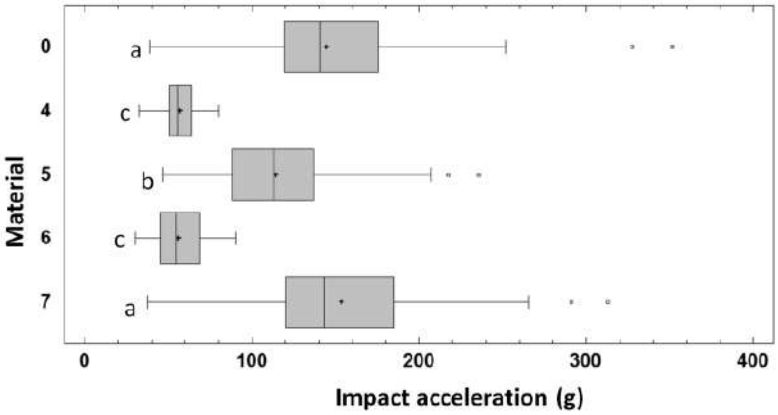

Figure 6. Box and whiskler plot for the variable drop impact higher than 30 G for each material.

Materials 0 and 7, showed the highest variability and the highest mean value of impacts, not having statistically differences between both material 7 and metallic surface. Material 5 was the following less impact absorbing and was statistically different to the rest of the materials. Material 4 and 6 showed the lower value variability and lower values of impact not having statistically differences between both but it has to take into account that for material 6 the 22.55% of data lower than 30 were not considered, Therefore material 6 is more absorbent material than 4. With these results the materials can be categorized into 5 distinct groups. A first group composed of materials 1, 2 and 3 which are the most shocking absorbing materials. A second group composed of the material 6. A third group composed of the material 4. A fourth group composed of the material 5 and the last group composed of the material 7 which behavior is the same as if the material had not been put on. In addition to the ability to absorb impacts, other factors like price, durability and impermeability should be taken into account to decide the best appropriate material for coating the different areas of the platform. The first three materials and 6 are not waterproof meanwhile material 4 is cover by a plastic surface making it waterproof.

4. Conclusions

The highest damage level produced in the citrus mobile platform prototype was registered from the bin-fillers to the bins.

In evaluation of the impacts in the classification process in the prototype, clear differences were found between the impacts from the two different bins. The final drop impact recorded in the external bin was clearly higher. On the other hand, the impacts recorded in the internal bin were more numerous and the final drop impact was lower. The channel 4 of the upper conveyor belt showed differences respect to the other channels.

In evaluation of the impact reducing capacity of different materials, materials 1, 2, 3, 4 and 6 showed a high capacity to absorb impacts being the material 4 the most adequate for its use in outdoor conditions.

The next step will be to analyse the damage on fresh fruit and according to those results to carry out the modifications in the platform prototype to reduce the damage as much as possible with the use, whenever possible, of some of the evaluated materials.

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