Analysis of the Mechanical Aggressiveness of Three Orange Packing Systems: Packing Table, Box Filler and Net Filler

F. J. García−Ramos, C. Valero, M. Ruiz−Altisent, J. Ortiz−Cañavate

Abstract. *Three different types of orange packing systems (packing table, box filler, and net filler) were analysed using an instrumented sphere IS 100 (7 cm ∅) in four orange packing lines in the region of Levante (Spain). Four packing tables, three box fillers, and three net fillers were tested by analysing impacts inflicted to fruit at the entrance and outlet transfer points of the machine. In general, entrance transfer points were more aggressive than outlet transfer points. Box filler was the least aggressive machine.*

Keywords. *Packing systems, Orange, Impact detection, Damage.*

Post−harvest processing of fresh fruit includes handling in fruit packing lines. Oranges are one of the most important fruits in terms of commercial value and international consumption (EU Commission, 2003). As other fresh fruits, oranges suffer mechanical damage during post−harvest handling. This damage can have an immediate consequence in terms of bruise peel wounds and peel compressions, which facilitate entry of pathogens (*Penicilium* sp.), especially reducing commercial shelf life (Barmore and Brown, 1982; Holmes et al., 1994; Tuset et al., 1997).

Most damage in packing lines is produced at transfer points between different elements or machines. Many studies have been carried out to identify critical transfer points in fruit packing lines using instrumented spheres (Zapp et al., 1989). Instrumented spheres help to identify the location of impacts on the fruit packing line (Brown et al., 1987; Bollen and De la Rue, 1990; Miller and Wagner, 1991; García et al., 1994) and impact characteristics such as intensity, velocity change and material hardness. Impact data are related to the bruise susceptibility of each fruit by establishing impact damage thresholds of each product (Schulte−Pason et al., 1990; Pang et al., 1991; Schulte−Pason et al., 1992; Mathew and Hyde, 1997, Baritelle and Hyde, 2001).

Several authors have suggested ways to improve critical transfer points (Guyer et al., 1991; Ortiz−Cañavate et al., 2001; García−Ramos et al., 2002) including the reduction of fall heights, use of padding materials, use of decelerator elements, and elimination of structural elements in receiving belts.

From the point of view of mechanical damage, one of the most critical elements of a handling line is the packing machine, where impacts are difficult to analyse visually. The possibility of reducing mechanical damage can be studied by using instrumented spheres at the entrance, the outlet, and inside the machine. For example, Marshall et al. (1992) reduced impact intensity by 45% in an apple bag filler by adding padding material to impact surfaces.

The objective of this work was to evaluate the mechanical aggressiveness of three types of packing systems (packing table, box filler, and net filler) commonly used in orange packing lines, using instrumented spheres. The goal is to incorporate the criterion of fruit quality when selecting packing equipment. The results from this study may be applicable to other fruits and vegetables (apples, pears, peaches, peppers, etc.) where these types of packing systems (packing tables, box fillers, and net fillers) are used.

Materials and Methods

Characteristics of impacts produced in the packing systems were analysed using an IS 100 instrumented sphere (161 g, 7−cm diameter) (García et al., 1994). Each impact was reported relative to the acceleration due to gravity (g), where g is equivalent to 9.8 m/s^2, with a sampling rate of 3906 Hz, g sensibility of 6 to 300 g and 3% accuracy. The g threshold to be considered zero impact was 30 g. Acquisition software was ‘Pcird’ version 3.03 (Techmark Inc., Lansing, Mich.). For each impact spheres recorded data on maximum acceleration (g) and velocity change (m/s).

Packing machines at four orange packing lines (A, B, C, and D) located in the area of Levante (Spain) were analysed. Ten different packing systems belonging to categories of packing table, box filler, and net filler were tested by taking eight measurement rounds (from entrance to outlet) with IS 100 spheres per machine. Characteristics of the packing systems analysed are shown in table 1. The four packing tables (in lines A, B, C, and D) were from four different

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Table 1. Characteristics of the packing systems analyzed.

Packing System	Number of Analyzed Machines	Packing Line
Packing table	4	A, B, C, D
Box filler	3	A, C, D
Net filler	3	A, C, D

manufacturers. The three box fillers (in lines A, C, and D) were also from three different manufacturers. Two (A and D) of the net fillers were from the same manufacturer while the net filer ‘C’ was from a different manufacturer.

Packing systems analysed were the most commonly used in Spanish orange packing lines at present. Many of the lines had three types of systems to provide different commercial products to the market. The main characteristics of the analysed packing systems were:

Packing table (fig. 1): consisting of a central transporting belt and lateral trays (parallel to the belt) where fruit was transferred. Workers manually took the fruit from the trays and put it in boxes. Tables had two transfer points, one at the entrance to the central transporting belt and another at the outlet to the lateral trays.

Box filler (fig. 2): The quantity of fruit placed in each box was determined by weight. Fruit was weighed on load cells. Weight was controlled by a microprocessor. Once the established weight was reached, fruit was placed in the box. Packing weight varied between 5 and 20 kg with a pre cision between 0.5% and 1%. The m a chine had a small lift, which lowered to place the fruit gently on the box located at the bottom, decreasing fall height (fig. 2). There were two transfer points, one at the entrance (from a transporter to the lift) and another at the outlet (from the lift to the box).

Net filler (fig. 3): The quantity of fruit to be placed in each package was determined by weight. Packing size varied between 0.5 and 5 kg with weight precision similar to the box filler. Working capacity varied between 20 and 40 nets/min. There were two transfer points, one at the entrance (from a transporter to the weighting system) and another at outlet (from the net to the receiving belt). The mechanics of these machines was more complicated, including several transfer points, and varied with the type of net filler. In some cases, a recirculation system was used to feed the machine until the set weight, so that the same fruit could have passed across the elements of the machine several times.

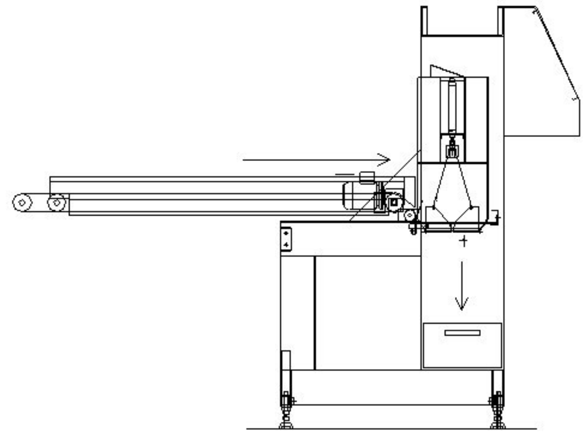


Figure 2. Box filler.

Results and Discussion

Packing Tables

Impact intensities on IS 100 spheres were higher at the entrance than at the outlet of the packing tables (fig. 4a and 4b). Entrance transfer points can be considered aggressive because the mean acceleration was higher than 80 g in the four packing tables (60 g would be an acceptable limit for oranges) (García−Ramos, 2000). However, the outlet transfer point in packing tables A, B, and C was quite acceptable, with mean accelerations under 60 g. An analysis of variance was performed on the variation of impact values in the four packing tables at each transfer point (entrance and outlet; table 2), differences were not significant. Even though packing tables were from four different manufacturers, the mechanical damage was similar.

Global information was obtained by relating maximum acceleration of impacts with velocity changes. Impact distribution (fig. 5) reflects the hardness of the material impacted by the IS 100 at each transfer point. The graph shows the maximum acceleration and changes in velocity of impacts recorded at the entrance (fig. 5a) and outlet (fig. 5b). At the graphic, the impact curves of three standard materials are displayed: steel, 3.2−mm Poron (P20125), and 6.4−mm Poron (P15250). Hardness of materials can be deduced by

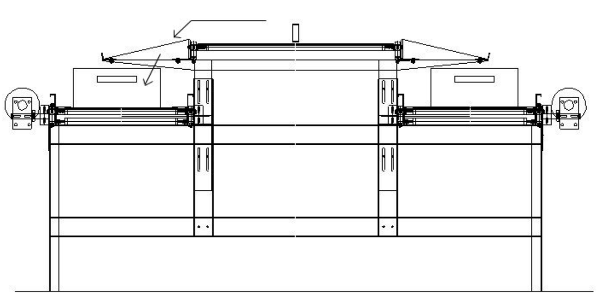


Figure 1. Packing table consisting of a central transporting belt and lateral trays.

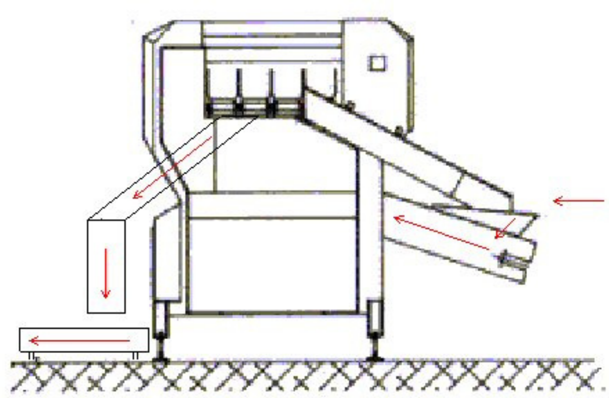
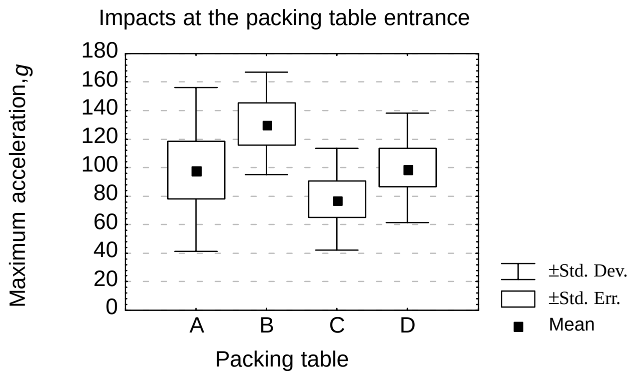
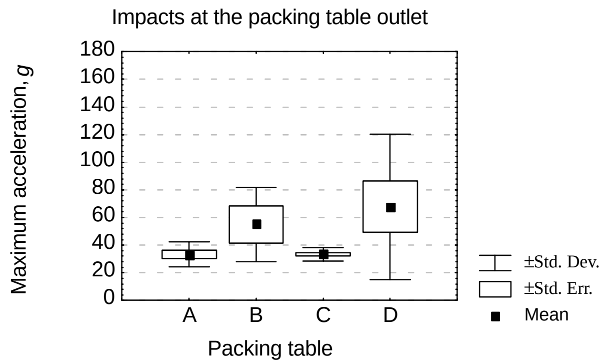


Figure 3. Net filler.

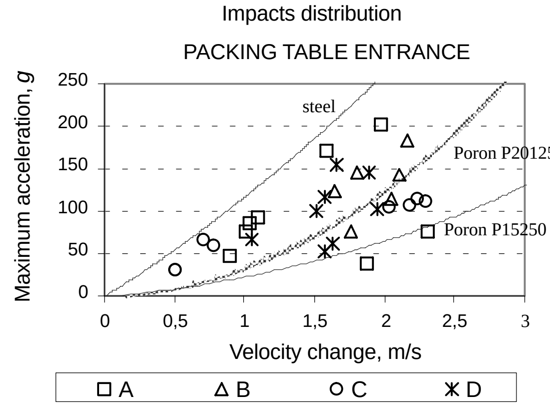


(a) Impact level at the packing table entrance.

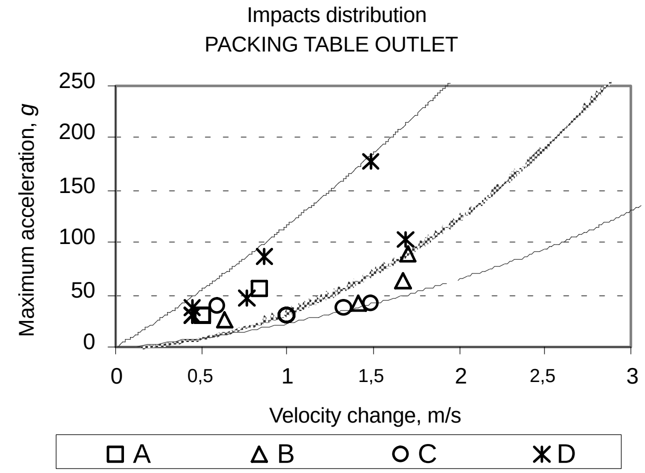


(b) Impact level at the packing table outlet.

Figure 4. Impact level graphics of the packing table.



(a) Impacts distribution at the packing table entrance.



(b) Impacts distribution at the packing table outlet.

Figure 5. Impacts distribution graphics of the packing tables.

analysing the location of the IS 100 impact data in relation to the standard curves.

At the entrance of packing tables B and D (fig. 5a), impacts were against soft surfaces (transporting belt and padding materials of the entrance ramp). However, at the entrance of packing tables A and C, the surfaces were different, with uneven intensities, probably due to the structural elements under the transporting belt. After analysing each outlet transfer point separately, it appeared that differences in the impacted materials (fig. 5b) were obtained because some impacts hit borders of trays while others hit another fruit. However, the impact intensity was quite low because the transference to the trays was gentle in most cases. In fact, many impacts were lower than 30 g (g threshold to be considered zero impact) and then not recorded by the IS 100.

Box Fillers

The intensity of the impacts at the entrance transfer points was rather variable between the three box fillers (fig. 6a). Mean acceleration of the impacts registered at the entrance of box fillers A and D were 88 and 161 g, respectively, representing a critical transfer point in both machines. An analysis of variance reflected a significant difference in the acceleration values at entrance transfer point in terms of the box filler (F = 11.6; table 3). This significant variation affected box fillers C and D.

Mean acceleration of impacts at outlet transfer points were all under 40 g (fig. 6b), and therefore were not aggressive. There was no significant difference in acceleration values at the outlet transfer point in terms of the box filler (F = 0.36; table 3).

Figure 7b shows hardness of surfaces impacted by fruit at outlet transfer points of three box fillers. Intensity of impacts at outlet transfer points were low in the three machines and quite homogeneous because the lift transfers the fruit to the box gently (in many cases impacts were lower than 30 g), always guaranteeing a low transfer height.

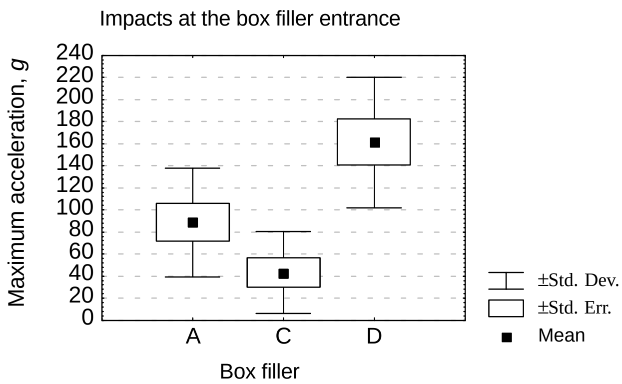
Comparing box filler entrance and outlet transfer points, the outlet was less aggressive. At the outlet transfer point, aggressiveness of the three box fillers analysed (A, C, and D) was acceptable. However, at the entrance transfer point, only box filler C could be considered non aggressive (fig. 7a).

Table 2. ANOVA of the impacts acceleration at the entrance and at the outlet of the packing tables.

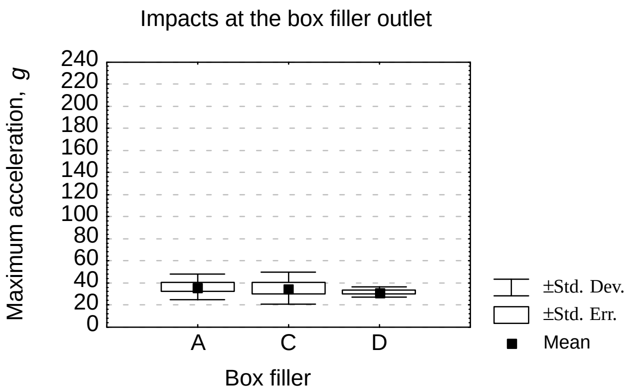
	df Effect	MS Effect	df Error	MS Error	F Value	p−level
Entrance	3	3218.95	26	1881.17	1.71	0.189
Outlet	3	2221.18	24	926.04791	2.39	0.092

Net Fillers

The mean accelerations of the impacts recorded at the entrance of net fillers (fig. 8a) was 73, 175, and 77 g for A, C, and D, respectively. These values represent critical transfer points in the three machines, mainly in net filler C. An analysis of variance was performed on the variation of impact values at the entrance and at the outlet of the net fillers

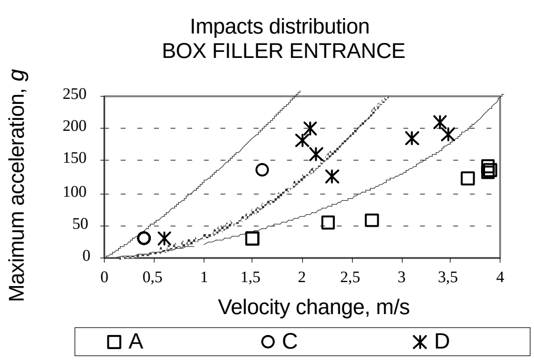


(a) Impact level at the box filler entrance.

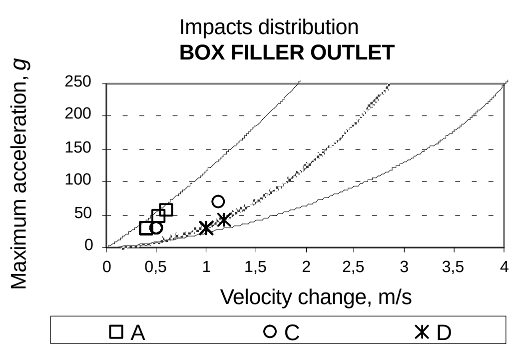


(b) Impact level at the box filler outlet.

Figure 6. Impact level graphics of the box filler.



(a) Impacts distribution at the box filler entrance.



(b) Impacts distribution at the box filler outlet.

Figure 7. Impacts distribution graphics of the box fillers.

Table 3. ANOVA of the impacts acceleration at the entrance and at the outlet of the box fillers.

	df Effect	MS Effect	df Error	MS Error	F value	p−level
Entrance	2	28341.95	21	2432.08	11.65[a]	0.0003
Outlet	2	44.45	21	121.61	0.36	0.698

[a] Significant difference.

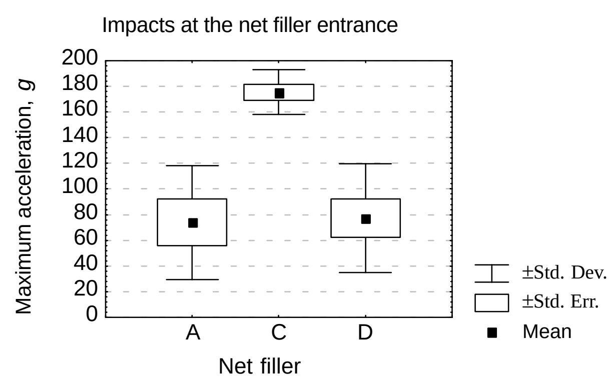
(table 4). Acceleration values showed significant differences between the three net fillers (A, C, and D) at the entrance transfer point (F = 19.5; table 4). Figure 9a shows that impacts were produced against hard surfaces (metallic reception trays) in the three machines. The higher values of the net filler C can be explained by an excessive transfer height at the entrance of the machine.

Comparison Between Packing Systems

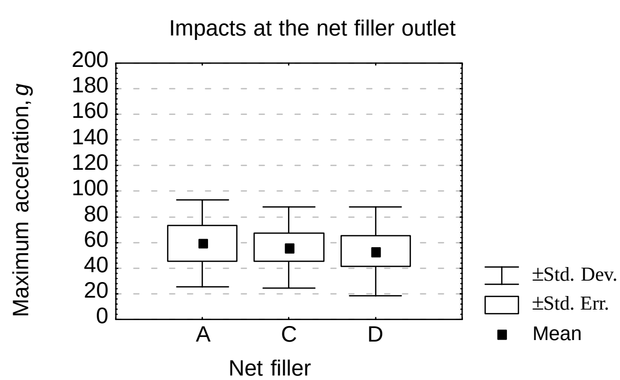
After a separate analysis of each type of packing system (packing table, box filler, and net filler) aggressiveness of the three systems should be compared. Figures 11 and 12 show impacts at the entrance and outlet of the 10 machines analysed (four packing tables, three box fillers, and three net fillers).

Aggressiveness of the entrance transfer points were similar among packing systems, with the exception of box filler D and net filler C (fig. 11). The entrance transfer point can be considered to be an aggressive transfer point in all the packing systems, with mean accelerations around 80 g (with the exception of box filler C).

Mean accelerations of impacts at outlet transfer points were all below 60g (not aggressive; fig 8b). There was no

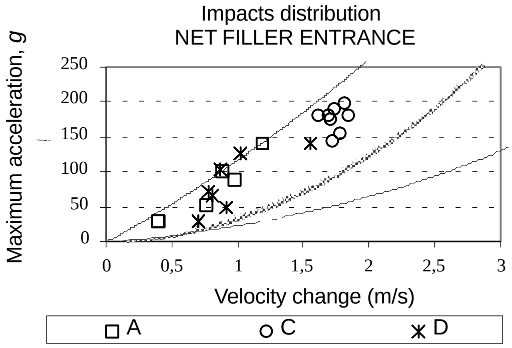


(a) Impact level at the net filler entrance.

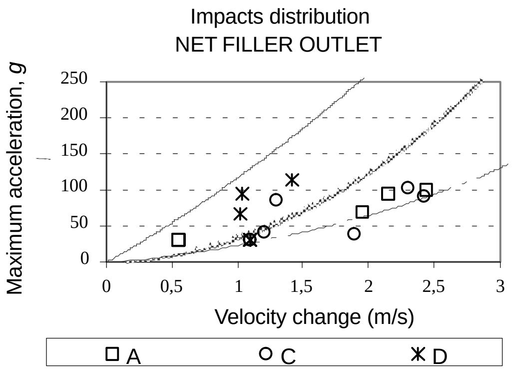


(b) Impact level at the net filler outlet.

Figure 8. Impact level graphics of the net fillers.



(a) Impacts distribution at the net filler entrance.



(b) Impacts distribution at the net filler outlet.

Figure 9. Impacts distribution graphics of the net fillers.

significant variation in acceleration values at outlet transfer points (F = 0.05; table 4). Impacts at the outlet transfer point of the three machines were against soft surfaces (areas of the receiving belt without structural elements, fig. 9b).

After comparing the three net fillers, the conclusion is that the outlet transfer is acceptable when the receiving belt is correctly positioned (without structural elements on the receiving area). However, the entrance is an aggressive transfer point, which varies with manufacturer (net fillers A and D were from the same manufacturer, and C from a different one).

In the case of the net fillers, an important finding was that the IS 100 registered an average of two impacts between the entrance and the outlet for each measure in the machines tested, this is, at internal transfer points inside the machine. Figure 10 shows impacts registered for the eight measurements in each machine. Mean accelerations of these additional internal impacts was 82, 165, and 85 g for net fillers A, C, and D, respectively. Many of these impacts were produced against hard surfaces, mainly at net fillers A and D (fig. 10). Packing tables and box fillers did not register internal impacts.

In the outlet transfer point, aggressiveness of the three packing systems shown to have been acceptable (fig. 12), the least aggressive being mean acceleration values below 40 g.

Table 4. ANOVA of the impacts acceleration at the entrance and at the outlet of the net fillers.

	df Effect	MS Effect	df Error	MS Error	F Value	p−Level
Entrance	2	25209.60	19	1291.71	19.51[a]	0.000025
Outlet	2	64.28	19	1108.40	0.057	0.943

[a] Significant difference.

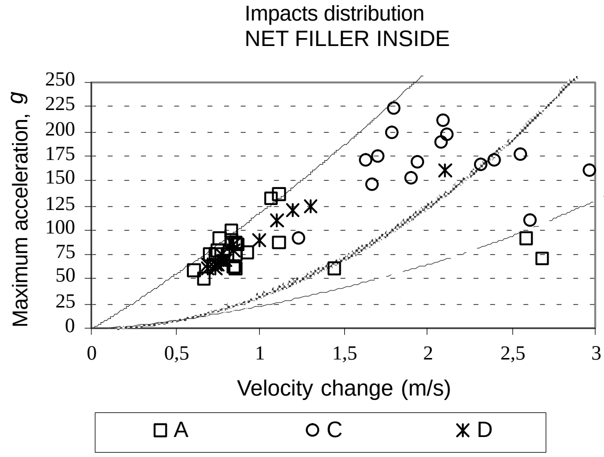


Figure 10. Impacts distributions at the net filler inside for the eight measures of the IS 100.

Packing tables and net fillers were similar, with mean acceleration values between 33 and 67 g.

Box fillers were shown to be least aggressive. Among the 10 machines analysed, box filler C offered lowest impact values. Packing tables and net fillers had similar values, but net fillers had an average of two high intensity internal impacts (above 80 g) between the entrance and the outlet transfer points, making them the most aggressive.

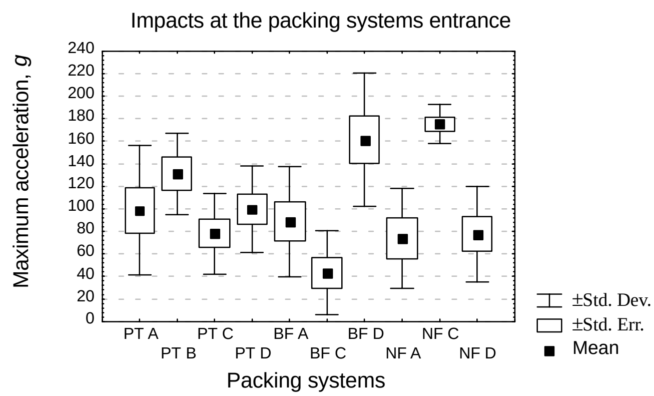


Figure 11. Impact level at the entrance of the packing systems (PT = packing table; BF = box filler; NF = net filler).

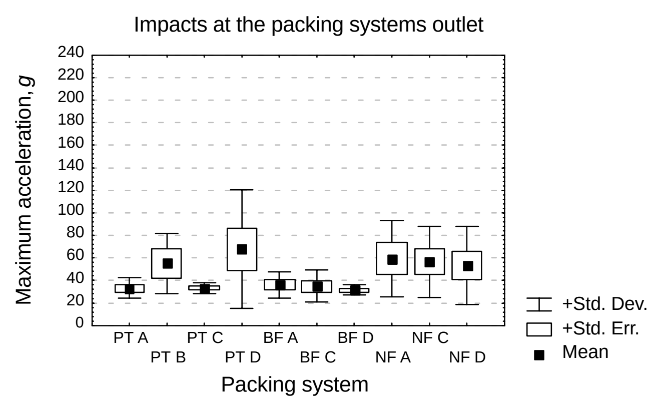


Figure 12. Impact level at the outlet of the packing systems (PT = packing table; BF = box filler; NF = net filler).

Conclusion

It has been shown that entrance points of fruit packaging systems provide greatest impact values for fruit. Therefore more attention should be focused on proper design. The use of reception plastic trays (in the case of net fillers) and the introduction of decelerator elements (powered brushes) to transfer the fruit gently inside the machine could be considered.

In packing tables, the entrance transfer point can be considered aggressive (mean accelerations above 80 g). The use of decelerator elements at the entrance of the central transporting should be considered.

In box fillers, the aggressiveness varies according to the manufacturer. Impact values vary widely at the entrance transfer point (from 43 to 161 g). The outlet transfer point is not aggressive (values below 40 g).

In net fillers, the aggressiveness showed significant differences in terms of the manufacturer. Entrance transfer points appear to be aggressive (impact values from 73 to 175 g). Outlet transfer points are acceptable, with mean accelerations around 56 g. Fruit from net fillers undergo an average of two additional internal impacts (besides those at the entrance and outlet) compared to the other packing systems. These impacts are produced against hard surfaces with mean accelerations above 80 g. Comparing the three packing systems; the box filler is the least aggressive.

Some machines (such as box filler C) can handle fruit without a risk of mechanical damage.

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