CHAIN CUSHIONING AND CUSHIONING MATERIALS AND THEIR RELATIVE EFFECTIVENESS [1]

by
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Abstract

Selecting the right cushioning material to minimize bruising at a reasonable cost is important when building or modifying potato harvesting and handling equipment. This report discusses the relative effectiveness of selected flat-surface cushioning and chain cushioning materials. It also discusses bruise thresholds and tolerable drop heights. The intent is to provide guidance in selecting and using cushioning materials.

Tuber Bruise Experiments

Whether a potato tuber gets bruised depends upon at least 6 tuber-related factors (size, radius of curvature at point of impact, temperature, hydration level, cultivar, and cropping practice) and two equipment-related factors (effective drop height and character of the impact surface). To measure the drop height at which tubers would just begin to bruise, 10 tubers were dropped individually from each of 10 different drop heights at each of three temperatures (50°, 60° and 70°F) onto a steel anvil. The tubers were 8 to 10-ounce Russet Burbank, dropped on the stem end. The number of tubers bruised gave the percent bruise for each drop height and tuber temperature. Figure 1 shows the results for 50° and 60°F. For any given bruise percentage, colder tubers had a lower drop height. The maximum drop heights for zero bruising were 1 and 1.2 inches for the 50° and 60° tubers, respectively. If 10% tuber damage is acceptable, then drop heights of 2 and 3 inches, respectively, can be tolerated.

Placing 1/4-inch thick Poron™ 15250 cushioning material on the anvil gave the additional data shown in Figure 2. Note that, while warmer tubers had slightly higher tolerable drop heights for a given percentage of bruise, cushioning increased tolerable heights much more. Where one inch is a tolerable drop height onto steel for no bruising, cushioning equivalent to 1/4-inch Poron™ increases the tolerable drop height to 8 inches for 50°F tubers; 10 inches for 60°F tubers.

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Figure 1. Percent of tubers bruised by drop height at 50° and 60°F.

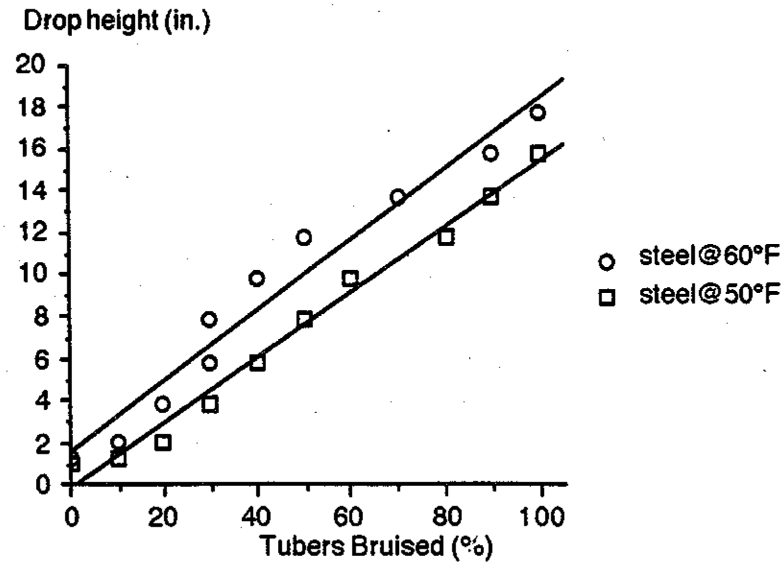
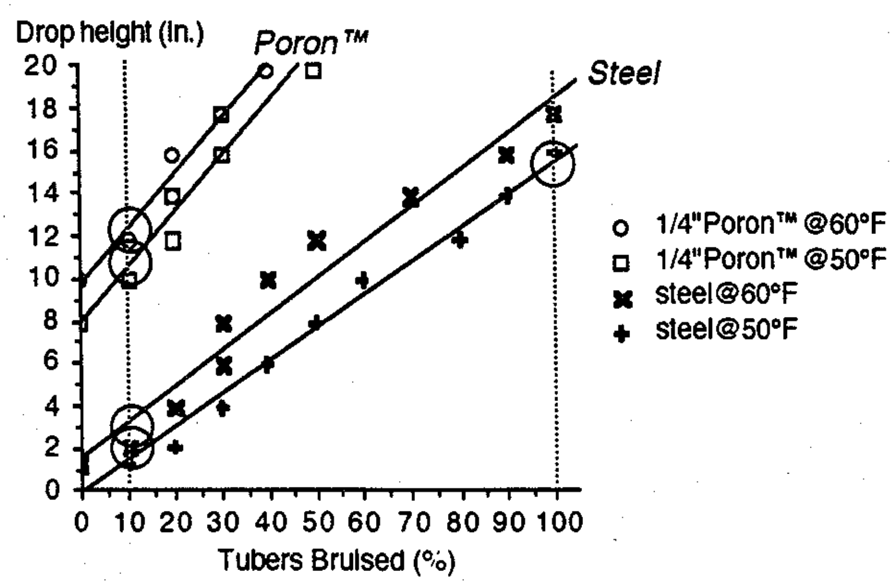


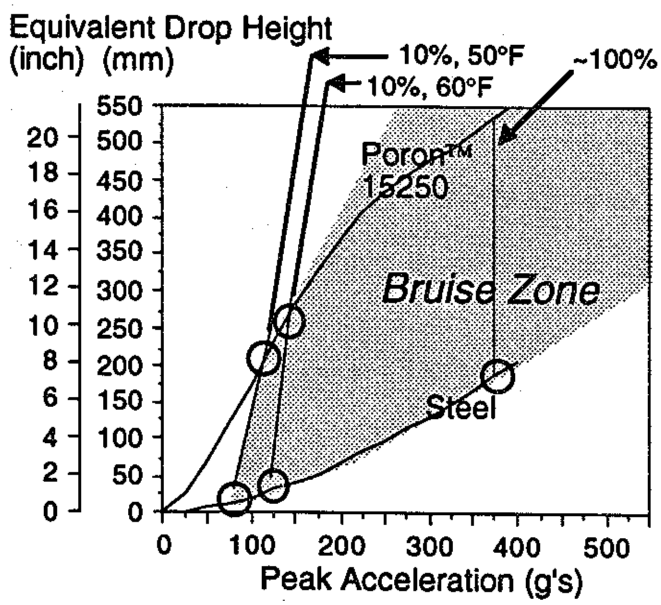
Figure 2. Percent bruise by drop height for steel and Poron™ 15250 at 50° and 60°F.



Evaluation of Impacts in Handling Equipment

The data of Figure 2 can be used in conjunction with the Instrumented Sphere (I.S.)[1] to evaluate handling equipment and as well as cushioning materials. This is accomplished by converting percent of tubers bruised to peak acceleration, a parameter measured by the I.S. That was done by dropping the I.S. from the same heights onto the same surfaces as were the tubers which gave the data for Figure 2. The results are in Figure 3. The circled points in figure 3 correspond to those in Figure 2. The nearly vertical straight lines associated with the circled points in Figure 3 are the bruise threshold lines for 50° and 60°F tubers dropped onto steel and 1/4-inch Poron ™. From this data, a zone of drop height vs. I.S. peak acceleration is identified (shaded area in Figure 3). When a tuber experiences an impact that falls in this zone, bruising will likely result. The shaded area in Figure 3 is called the "bruise zone."

Figure 3. Peak Acceleration by drop height. Includes 10% bruise thresholds and surface reference curves for steel and 1/4-inch Poron™.



When the I.S. is run through handling equipment and the results are plotted on top of Figure 3, specific areas within the equipment can be identified and the potential for tuber damage assessed (Figure 4 and 5). The symbols show the character and location of impacts that occurred. Impacts falling in the bruise zone (the shaded area) will likely cause tuber bruise. The further to the right in the bruise zone, the more likely that bruising will occur.

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1 Zapp, H.R., Ehlert, G.K. Brown, P. Armstrong and S. Sober. 1990. Advanced instrumented sphere (IS) for impact measurements. Transactions of the ASAE 33(3):955-960.

The packing line had one 500-g impact in the weigh sizer output - the dark triangle in the upper right corner of Figure 4, guaranteed to bruise tubers!. The harvester (Figure 5) had a damaging impact at the center of the drop into the secondary where side-cast tubers fall, and it needed cushioning on the side of the side elevator opposite the rear cross and on side of the boom (picking table) opposite the top of the side elevator. In the latter two instances, tubers coming onto the conveyor rolled across it and hit the unpadded side.

Figure 4. Impacts in one packing line.

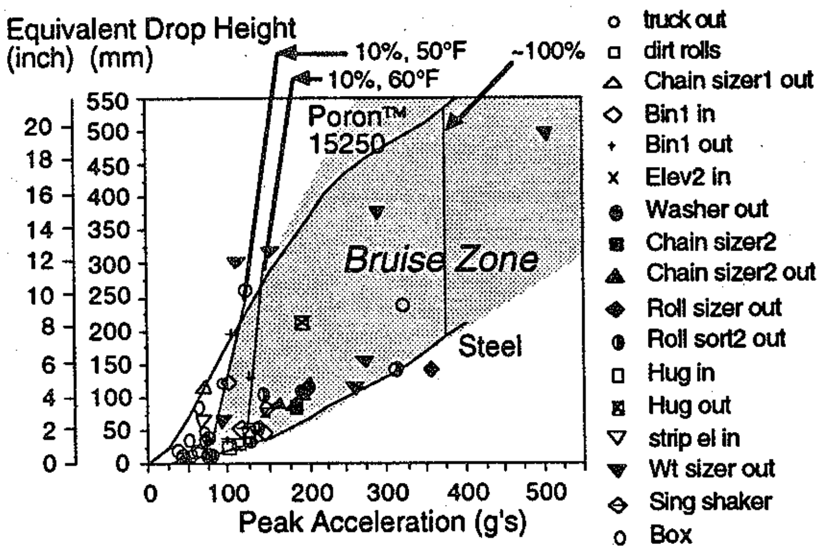
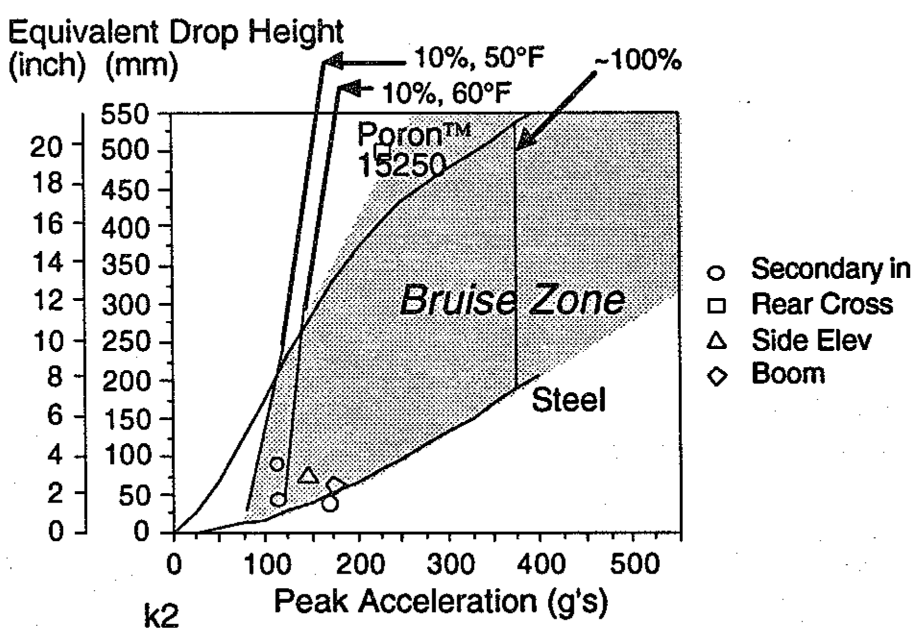


Figure 5. Some impacts in a better-than-average potato harvester.



Comparison of Flat Surface Cushioning Materials

Dropping the instrumented Sphere from successively increasing heights onto steel, 5/16-inch rubber belting, 1/4-inch Poron™ 15250, 1/2-inch Poron™ 15500, and 3/4-inch NoBruze™ allows us to compare the cushioning ability of these materials. The drop heights and corresponding peak accelerations are plotted in Figure 6. The materials are listed in order of decreasing cushioning ability.

Figure 6. Results of dropping the I.S. from successively increasing heights onto the surfaces shown.

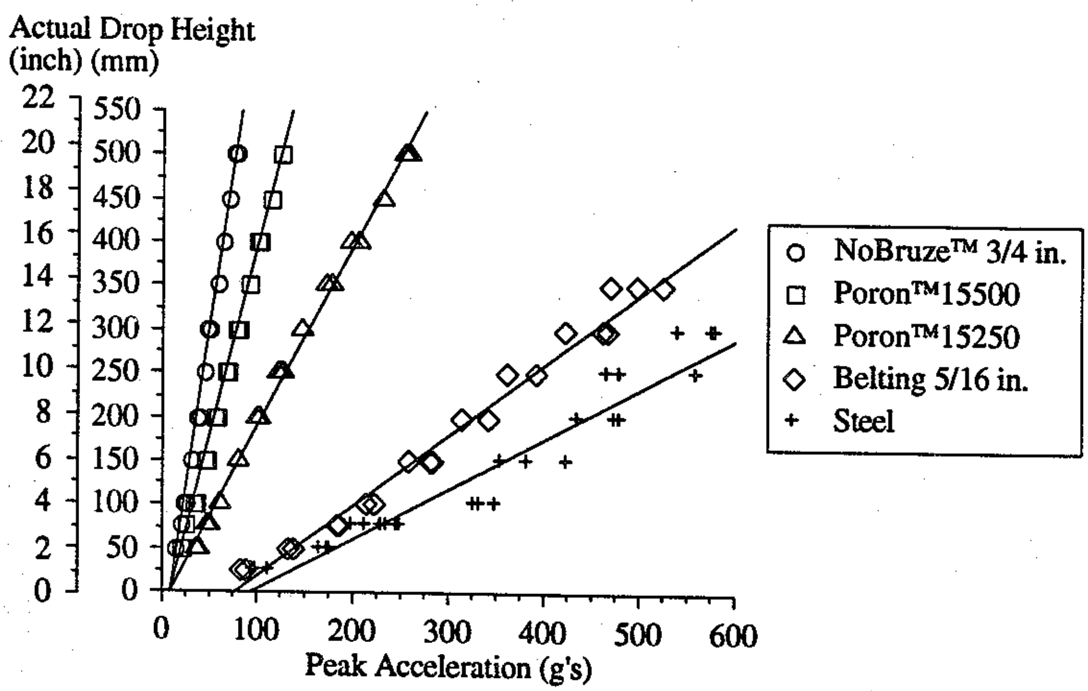
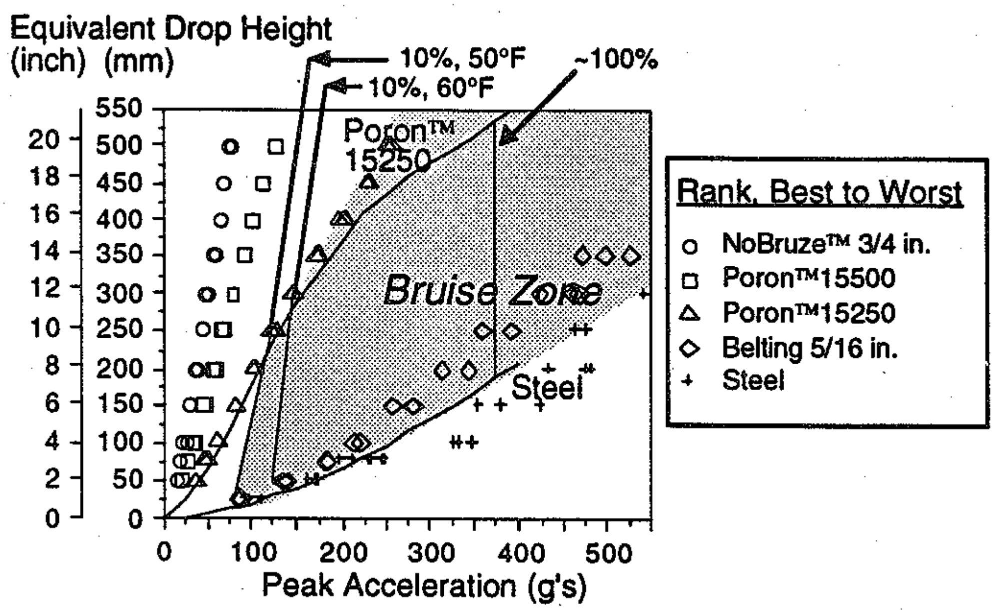


Figure 7 below superimposes the plot of Figure 6 onto the bruise zone of Figure 3 to show the potential for bruising from each of the cushioning materials.

Note that the 5/16-inch belting is almost as bad as the bare steel, whereas the 1/2-inch Poron™ 15500 and the 3/4-inch NoBruze™ are both better cushioning than the 1/4-inch Poron™ 15250 (because they are thicker). These data show that good cushioning materials are available and they can be used to reduce tuber damage. Note that Poron™ cannot be used alone for cushioning potatoes because of its low abrasion resistance. It is very useful, however, when covered with a thin sheet of Neoprene™ or belting. NoBruze™, on the other hand, has been reported by its suppliers to have good abrasion resistance.

Figure 7. Cushioning Material Comparison.

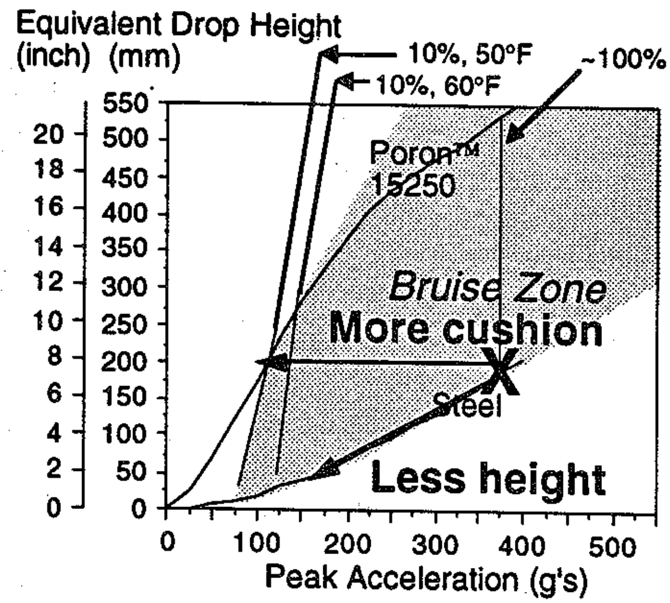


Using These Results

How can this information be used to help make decisions about equipment modification(s) that result in less tuber damage? Figure 8 shows that adding cushioning changes the impact along a horizontal line toward the left; reducing drop height changes impact along the line for whatever cushioning material currently is used. For example, in Figure 8, if an impact in a handling system occurred at the large X, which would be a severe impact on a hard, steel-like surface, then adding 1/4-inch Poron™ 15250 to that surface would change the resulting impact along the horizontal arrow toward the left, moving it to the Poron™ 15250 line in Figure 8, and thus out of the bruise zone. Reducing the drop height in the equipment instead of adding cushioning would move the impact along the steel line in Figure 8, and the drop height would have to be reduced from the current 8 inches to 1 inch to get out of the bruise zone.

The amount and cost of cushioning needed to reach an acceptable damage level can be compared against the drop reduction needed. If drop height reduction is not feasible either from the cost or equipment design standpoint, then cushioning is the only viable option. Most often damage reduction can best be achieved by a combination of drop height reduction and cushioning. Drop height reduction can be achieved partially by chain speed to ground speed adjustments (for harvesters) or conveyor speed to flow rate adjustments (for handling equipment) to keep the equipment filled to capacity with tubers as much as possible.

Figure 8. Effects of adding cushioning and/or reducing drop height.

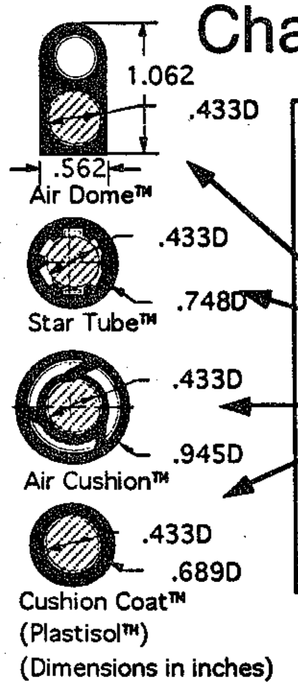


Chain Cushioning Materials

Several chain cushioning materials and designs were also evaluated. The Instrumented Sphere was dropped from known heights onto them and the impacts were compared with those on 1/4-inch Poron™ as a reference. Figure 9 shows the materials ranked in order of cushioning ability and tolerable drop height for 10% tuber damage. Note that this is only a limited sampling of the materials commercially available. Peg Link™ and Air Dome™ were the best cushioning materials configurations. With peg link, the impacts were on the end of the peg. Somewhat surprisingly, Star Tube™ was better than Air Cushion™ , probably because Air Cushion™ tended to "bottom out" at impact. The tolerable drop heights identified for various chain link cushioning in Figure 9 may be too high because of the small diameter of the rods, especially the bare steel rod. The small rod diameter tends to concentrate the stress on the tuber during impact and will cause bruise at a smaller drop height than for a flat surface.

Figure 9. Chain cushioning materials in order of best to least cushioning ability.

Chain Cushion Materials



Material	Tolerable Drop (inch)	Equivalent Cushioning
Peg Link™	8 +	1/4" Poron™ +
Air Dome™	8 +	1/4" Poron™
Star Tube™8		1/8" Poron™
Air Cushion™	6	variable
Cushion Coat™	6	variable
Steel rod	4	almost none

Summary

Good cushioning materials are available. Ordinary rubber belting is not one of them. In many cases, good cushioning may cost no more than the belting that is now being used. Often, adding cushioning may be easier and more cost effective than reducing drop height. The amount of drop-height reduction or additional cushioning needed can be determined by Instrumented Sphere evaluation of the equipment. Effective drop height, however, can often be greatly reduced at little cost by adjusting conveyor speeds to keep conveyors full of tubers.