Minimizing Apple Bruising in the Packing Line
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by

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Apples on the tree are generally free of bruise damage, but after traveling through a series of handling processes, apples in the retail store often show bruises. In general, the culprits inflicting most of the bruises are existing apple packing lines, when compared to other postharvest related operations (orchard operations/handling, transportation). Analysis of packing lines using a computerized impact measuring sphere that is the approximate size of an apple, laboratory test results, and observations of transfer designs and techniques identified transfer methods between packing line components that minimize apple bruising. Fundamental recommendations in order of importance are:

1. Minimize or eliminate height differences at transfer points between components.
2. Control fruit velocity at transfers by using active or passive control devices.
3. Use cushioning materials and designs to absorb impact.
4. Synchronize timing between components.
5. Limit component operating speeds.
6. Eliminate high velocity impacts.

Many of today's handling operations subject fruit to impact or compression forces which bruise fruit. Bruising lowers the fruit grade, increases decay and ultimately results in lost revenue which affects packers, producers and the industry as a whole. When the total bruise area on an apple exceeds that of a 0.50 in. diameter circle, the apple grade is reduced from U.S. Extra Fancy to U.S. Fancy (USDA, 1978). In 1986, studies investigating eight packing lines found the average reduction in grade due to bruising fell from U.S. Extra Fancy to slightly below U.S. No. 1 (Brown et al., 1989). This study assumed all input apples were U.S. Extra Fancy and all fruit was packed. Such a drop in grade is a 20% drop in revenue based on the above conditions and marketing strategies. As an example, assume each input bin contains 20 bushels, of which 75% are U.S. Extra Fancy; 50 bins are packed/day, with a 20% drop in revenue (approximately $2.00/bushel). Thus, 50 bins/day x .75 x 20 bushels/bin x $2.00/bushel = $1500/day. The importance of eliminating bruising is clearly significant, and the pay-back period on even major changes will be within a year.

Experimental Findings and Energy Relationships in the Packinghouse

The major problems with packing lines are excessive height differences between line components, lack of control of rolling velocity, and lack of cushioning on impact surfaces. The area causing the most bruising on packing lines is at the transfers between components. The 1986 study found packing lines average seven transfers with an average height difference of 6.7 inches. In theory a packing line should be level at all transfer points. However, in practice this is not always possible, especially on lines already in place.

The severity of impact at each transfer depends upon the energy at the transfer and the surface being struck (impacted) by the apple. In this case, the energy in each apple comes from the height difference or change that occurs at the transfer. The height change can be in the form of a drop or a ramp. The smaller the vertical height change, the lower the fruit velocity at impact, which means less energy is absorbed by the apple causing less bruising.

An apple hitting a hard surface has a high peak deceleration for a fraction of a second. As velocity increases, peak deceleration increases, and the bruise becomes more severe. Cushioning "catches" the fruit to some degree, depending on the cushioning, and causes the fruit to decelerate over a longer period of time, thus reducing the peak force of the impact. Cushioning also tends to surround the fruit as it is absorbed into the cushioning, creating a greater surface contact area and in turn decreasing the stress on the fruit. Cushioning on ramps is also beneficial as it cushions the small impacts that occur during apple rolling and it reduces the rolling velocity.

Designing, Modifying and Improving Transfers on Packing Lines

Ideally, fruit flows through a transfer smoothly and always in control because controlled fruit maintains a constant velocity through a transfer without allowing gravity to increase fruit velocity. Optimal transfers limit or eliminate any height differences (changes) at the transfer points.

Optimal transfers can be addressed from three basic viewpoints; compatible and proper design of components; using specially designed transfers at time of installation; and modifying transfers on existing lines. Minimum fruit energy change is the one consideration that should be the basis for every transfer when designed, installed or modified.

Minimizing Height Differential

Once a line is installed and height differentials exist between components, the potential energy of the transfer is established. The problem is how to dissipate the resulting energy when the apple makes the height change. Minimizing height changes at transfers is achieved by combining component design and installation. For example, designing conveyor end rollers with small diameters allows components to be butted together with only a slight gap to bridge or small height change to make. The bridge may be a short ramp slightly angled or flat, or a powered brush (Figure 1, 2, and 3).

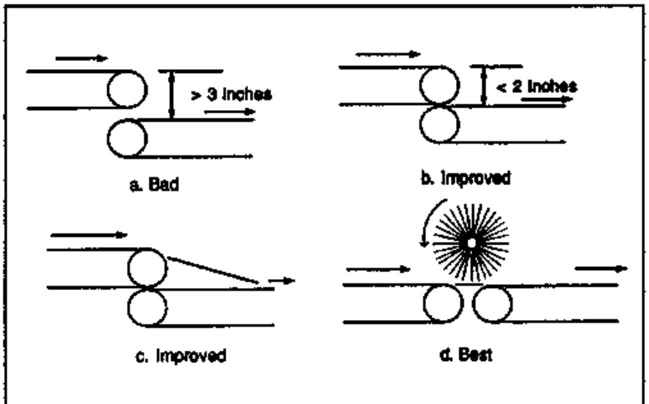


Figure 1, Height Differentials: Basic Transfer Considerations.

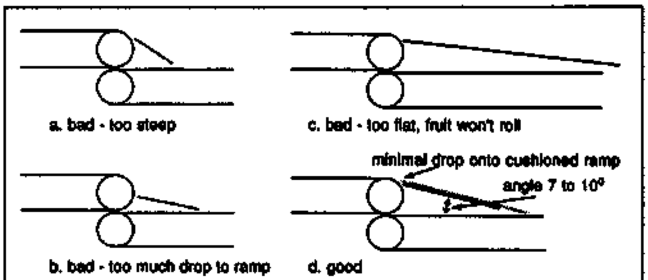


Figure 2, Height Differentials: Ramp Design.

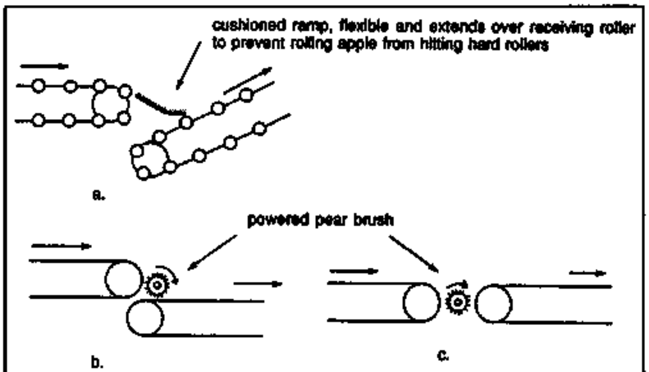
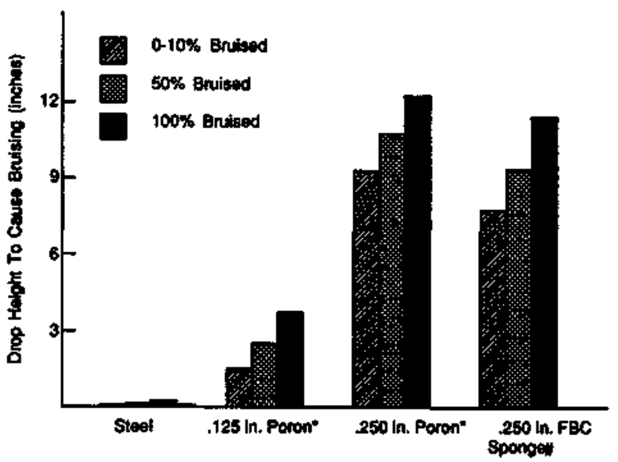


Figure 3, Additional Transfer Techniques.

Constructing packing line components with heights that can be easily adjusted is essential. In situations where components cannot be matched to equal heights at transfers, such as toward the beginning section of a line, consider incorporating chain or roller conveyors to gently lift fruit from one water tank, make the height change, and place the fruit into another tank, eliminating free falling or rolling. In addition, water tanks, which can only be used ahead of the dryer, act as accumulators which feed the next component in the line at full capacity, limiting bruising and increasing efficiency. However, the water in these tanks must be changed frequently to maintain sanitary conditions.

Impact Energy Absorption

Energy absorption in this section refers to cushioning. Cushioning is not an alternative to reducing height differentials, but rather is a necessary tool to reduce the chance of bruising. Examples showing bruising potential thresholds related to drop heights and common surfaces for McIntosh apples are given in Figure 4. Bruising begins at drops of less than 0.1 inch onto a hard surface, but can be avoided up to 9 in. when a 0.250 in. thick cushion is used.



* Rogers Corp, Box 158, East Woodstock, CT 06244. Poron 4701-05-20125-1637 and Poron 4701-05-15250-1637.

Uniroyal Plastics, 312 N. Hill St., Mishawaka, IN 46544. FBC Sponge with 11-mil Green Vinyl Cover.

Figure 4, Impact Energy Absorption: Bruising on Varying Surfaces (Schulte Pason et al., 1990).

Cushioning comes in many types, densities and thicknesses. A 0.250 in. thickness of closed cell sponge having a density of 5.5 to 15 lb/ft^3 should be used whenever rolling or free fall damaging impacts might occur on hard surfaces such as metal, wood, plastic, belting or inadequate cushioning (Brown et al., 1990b).

Equally important is maintaining and replacing cushioning materials. Wear, deterioration, and build-up of waxes, dirt and other substances cause cushioning materials to become ineffective. Cushioning that is too thin or has deteriorated can even cause larger bruises than if no cushioning were present.

In situations where apples drop onto a conveyor belt where cushioning cannot be applied, the effect of cushioning is best accomplished by ensuring that a large area of belting around the point of fruit impact is freely suspended (not supported underneath by steel) (Figure 5).

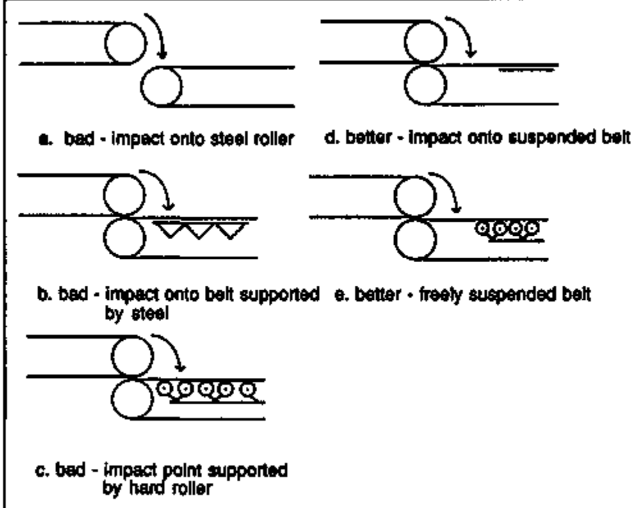


Figure 5, Impact Energy Absorption: Supported vs. Unsupported Belting.

Dissipating Excess Energy

It is inevitable that some type of transfer with a height difference that causes bruising will exist between components on a packing line. The underlying solution for such a transfer is to actively control the energy or to passively dissipate the energy by breaking the energy of the transfer into multiple low-energy segments.

Active control involves some type of mechanical energy input and is generally the most effective technique, but also requires more design and installation expertise and expense. The payback is higher quality fruit. One commonly used active technique is a cushioned transfer ramp with a powered brush mounted overhead (Figure 6).

The brush is cylindrical, mounted horizontal and perpendicular to the conveyor, and rotates so that the bristles travel with the flow of fruit to move it

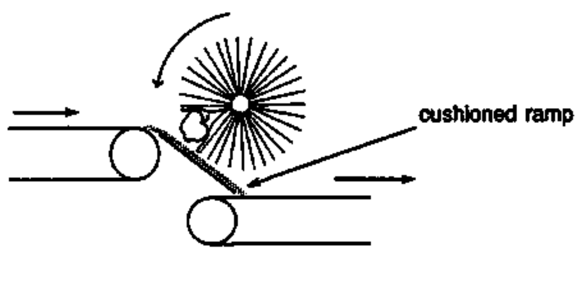


Figure 6, Active Energy Control: Overhead powered brush.

over the transfer point at a constant controlled velocity. A number of ideas are very important with these brushes. The bristles should be stiff enough to catch and hold (pocket) the fruit, but not so stiff as to puncture the fruit. Brush height (clearance) above the ramp is determined by apple size, bristle length, and bristle stiffness. Bristle stiffness is related to the material properties of the bristle, the length of the bristle (brush diameter - core diameter), and the diameter of the bristle itself. An important adjustment is the rotational speed of the brush. Adjust the conveying velocity of the brush so it is equivalent to the speed of the line component following the brush. If the brush is rotating too fast, maximum effectiveness will not be obtained because the brush will not effectively reduce fruit velocity. A rotation which is too slow will cause fruit coming into the brush to impact fruit already at the brush.

Another active technique is powered "pear brushes" under the fruit. A pear brush is generally 3 to 4 in. in diameter with 1.0 to 1.5 in. long medium-soft bristles (Figure 7). If the bristles are too soft, the apples may hit the brush core and be bruised. Depending on the transfer, they can be used individually or in multiples between successive line components. An important criteria for these pear brushes is that they do not toss the fruit

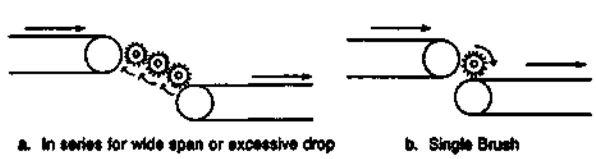


Figure 7, Active Energy Control: Pear Brush(es).

over the brushes and onto the next component. If not properly adjusted to maintain constant fruit velocity they can add energy to the transfer!

Passive techniques for dissipating fruit energy include curtains (blankets) and flaps (Figure 8). These are relatively easy to install and inexpensive, but often times ineffective. The effectiveness of curtains and flaps not only depends on their material, proper installation and adjustment, but on apple size, which is often quite variable. Curtains are hung over a transfer ramp and draped onto the ramp so that the fruit is slowed but not stopped. Flaps act much the same way but are usually stiffer, cut in vertically hanging strips and not as much draping is involved. Ideally, curtains and flaps

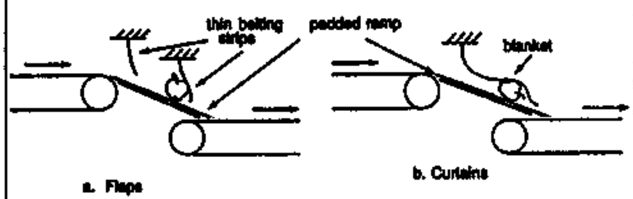


Figure 8, Passive Energy Control.

require adjusting based on size, shape, and rolling velocity of the fruit. If the curtain or flap does not slow the fruit adequately, fruit velocity remains high enough to cause bruising. If a curtain or flap is too restrictive, fruit-to-fruit impacts cause bruises and fruit flow can bridge or backup. Maintaining curtains and flaps is important because dirt and wax build-up degrades their properties. In some cases, curtains or flaps are beneficial, but effective operation requires more consideration than just hanging something over a transfer ramp.

Timing and Synchronizing

Often, serious bruising on packing lines occurs where minimal height differentials exist. The cause for such damage is often due to poor timing of one or more hard-surfaced components. It is crucial that individual components be designed and adjusted to allow synchronization between components (Figure 9). The fruit must flow evenly without high velocity fruit-to-fruit impacts. For example, proper timing or synchronization is very critical at the transfer from the singulator to the

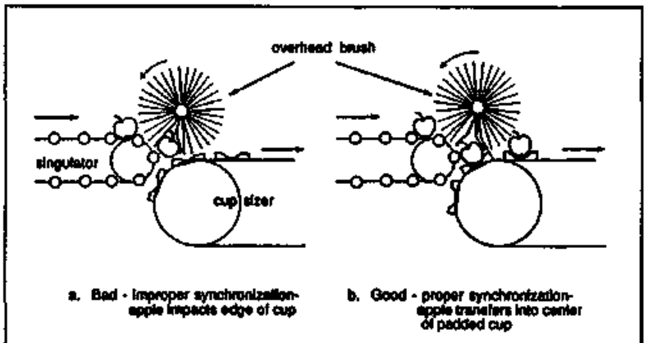


Figure 9, Synchronization of components.

sizer cup. This is generally a rough transfer even with proper timing, and poor timing only compounds the problem. Where cup sizers are used, the severity and number of impacts at this transfer can be reduced by adding a 0.125 in. thickness of quality cushioning material (eg., Poron 4701-05-20125-1637) to the inside of each cup.

Operating Speed

Bruising is significantly increased when operating speeds are too high. Components that are operating too fast add energy to the fruit through excessive vibrations and bouncing as the belts or rollers pass over sprockets or other support locations. Excessive component speeds also increase the velocity of a fruit as it leaves a component and transfers to another, compounding the problem of controlling speeds and energy at transfers.

Managing line load is a concept closely related to operating speed. Packing lines operating at capacity have two major advantages. Full lines keep individual fruit restrained as limited free space exists for movement which could otherwise cause bruising. This includes restrained flow of fruit at transfers. Ramps, for example, full of fruit, keep free rolling from occurring. Additionally, lines operating at or near capacity are efficient.

Fruit-to-Fruit Impacts

Fruit-to-fruit impacts are a common problem. This occurs when fruit flow makes a sharp turn, or when sized fruit drops to a cross-conveyor. In the latter situation the fruit entering the cross conveyor should be redirected (diverted) to keep it moving in the same direction as the cross conveyor before entering the flow of fruit (Marshall et al., 1989) (Figure 10). This prevents fruit entering the cross conveyor from directly impacting fruit already present on the cross conveyor. Smoothly diverting incoming fruit also prevents impacts which often occur where fruit contacts the side portion of the cross conveyor after dropping or rolling from the top conveyor.

Techniques for diverting fruit vary based on such things as the space between the top and cross conveyors, the number of channels entering the

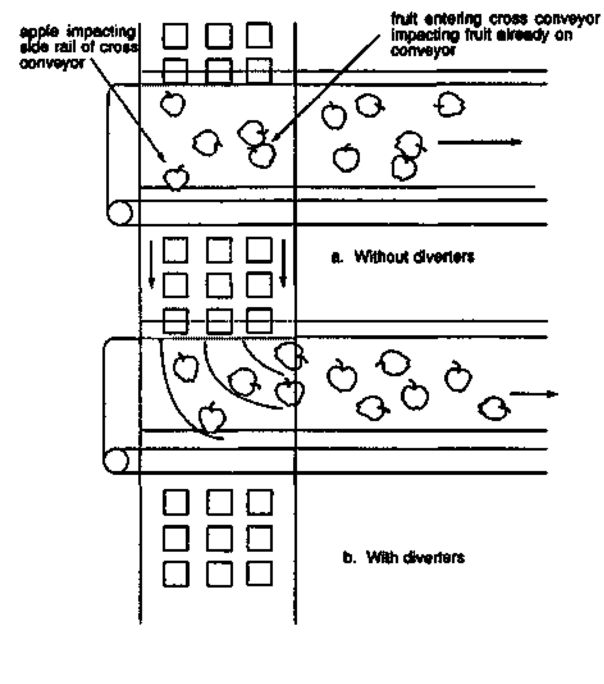


Figure 10, Fruit entering cross conveyor from sizer conveyor.

cross conveyor, and/or the angle of drop. Diverters could be shaped and formed using old conveyor belting or cushioned sheet metal, additional cushioned ramping, or more structured chutes. Additionally, protect (channel) fruit already on the cross conveyor so it cannot be hit by entering fruit, and cushion all diverters!

Recommendations

The suggestions and recommendations within this report result from analyzing packing lines and observing transfer techniques which minimize bruising. Conditions which minimize bruising in the packing line include:

- Minimize height differences at transfer locations between components.
- Adequately cushion all locations where apples can impact a hard surface; consider suspension of conveyor belts where apples impact belts.
- Control the energy of a transfer with overhead power brushes or with pear brushes that control fruit velocity.
- Reduce fruit velocity and energy on transfer where height differences exist by using flaps, curtains or blankets.
- Time or synchronize all components and transfers to achieve constant flow of apples over the entire packing line (Volume = Capacity).
- Eliminate all fruit-to-fruit impacts.

Techniques for Evaluating Packing Lines

Two techniques were used to evaluate the bruising potential of packing lines (Brown et al., 1990a). The first technique used bruise-free golden delicious apples over a line while the line was in full operation and packing a red colored variety of apple. As the test apples passed specified points along the line, they were removed to determine the total amount of bruising that occurred up to that specified location along the line (Figure 11). The second technique involved using an Instrumented Sphere (IS). The IS was developed jointly by MSU and USDA researchers and is commercially produced by Techmark Inc., Lansing MI. A sphere the size of a large apple, the IS internally contains a small computer with memory and an impact sensor (Zapp et al., 1990). The IS runs over a packing line several times to measure and record the impacts caused by the line.

The apple bruise data provides a direct measurement of the bruising caused by a packing line (Brown et al., 1989). The IS impact data, along with laboratory test results that relate actual bruising data with impact data, provide a good estimate of the bruising caused by a packing line (Schulte Pason et al., 1990).

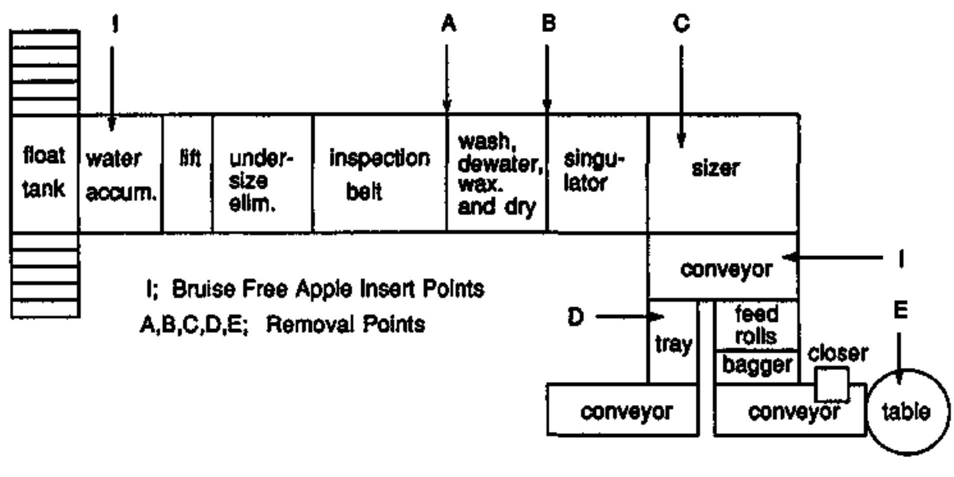


Figure 11. Sampling points along typical packing line, 1986.

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