HARVESTING BLUEBERRIES:
A GUIDE TO MACHINE PICK BLUEBERRIES FOR FRESH MARKET

Summary

Blueberries sold on the fresh market can be a high-value commodity. Unfortunately, harvesting high-quality fruits has become challenging due to constraints associated with high costs and decreasing availability of hand harvest crews. Many growers have turned to machine harvesters to pick blueberries for fresh markets as they reduce both harvesting and labor costs, but quality can be compromised due to mechanical impacts that result in fruit bruising, softness, and losses in fruit quality. New modified machine harvesters can improve fruit quality but must be implemented correctly. Regardless of whether a grower is machine or hand harvesting their blueberries, various pre- and postharvest factors are also critical to consider to maximize quality and food safety. This publication provides information on various practices that can improve harvest efficiency and fruit quality when machine harvesting blueberry for fresh market.

Introduction

Harvesting specialty crops for the fresh market has become increasingly challenging due to increasing labor costs and low worker availability. For blueberry, fruits destined for the fresh market were traditionally harvested by hand. However, labor challenges have led many growers to machine pick some or all of their fresh-market blueberries. Blueberry is a delicate fruit and impacts experienced during machine harvest operations can cause internal bruising that leads to reduced fruit quality and shorter shelf life (Figure 1). There are new mechanical harvesters built to reduce the incidence of internal bruising, leading to improved fresh market quality compared to harvesters built 20 to 30 years ago. Modifications to these new harvesters include an air fruit detachment system to eliminate fruit-shaking rod contact, as well as catcher plates and interior surfaces made with softer materials that reduce impact forces sustained when dropping fruits make contact with harvester surfaces. These modified harvesters must be operated correctly to maximize harvest efficiency and fruit quality. Furthermore, other pre- and postharvest factors should be considered to maximize quality and food safety in both machine- and handpicked scenarios.

Field Establishment

Success with any agricultural operation depends on proper field establishment. For machine-picking scenarios, important establishment considerations include cultivar selection, planting and field design, and implementation of pruning and training systems that are compatible with machine harvest.

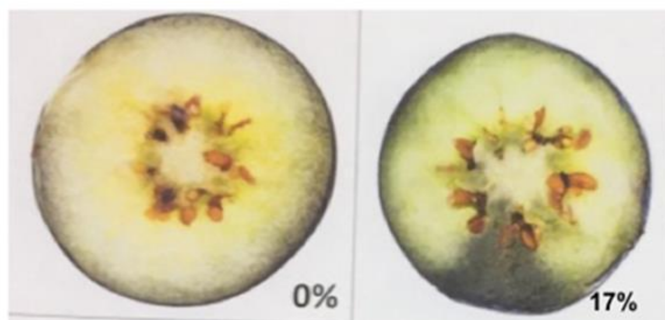

Figure 1. No internal bruising (*left*) versus a berry with 17% internal bruising damage (*right*), which is indicated by the darkened, wedge-shaped section. Photo by Seiya Saito, USDA ARS.

Cultivar

Cultivar choice is very important for a successful blueberry operation. Blueberries produced for the fresh market should have superior postharvest quality, meaning they maintain firmness and do not decay or shrivel shortly after harvest. In addition, selected cultivars should have good size, texture, and flavor profiles as well as a plant architecture suitable for machine harvesting. Also, in a machine-picking situation, cultivar and management need to be synergized to ensure efficient harvesting while maximizing fruit quality. Fruit firmness and storability are considered important characteristics, but especially so when machine picking (Ballington 1990; Olmstead and Finn 2014).

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However, studies have shown there is not a strong correlation between fruit firmness and internal bruising for many cultivars (Moggia et al. 2017; Wei Yang, unpublished data). For example, eleven cultivars of northern highbush (73% of cultivars tested) and three cultivars of rabbiteye (27% of cultivars tested) blueberries subjected to drop tests to simulate machine harvesting had correlation coefficients less than 0.50 (Figure 2). That is, incidence of bruising was related to fruit firmness less than 50% of the time.

One weakness of firmness measurements is that they only measure firmness at one point along the equatorial axis of the fruit and may simply miss detecting softened, bruised tissue that may develop away from the point of measurement. Resistance to internal bruising may be a better quality indicator than fruit firmness for assessing cultivar suitability for mechanical harvest. Cultivars that are resistant to internal bruising show slow internal bruising development. Furthermore, northern highbush cultivars that are better adapted to hot summer temperatures are more desirable for both machine and hand harvest. Hot air temperature during harvest can accelerate bruising and pulp softening, thus decreasing fruit firmness, quality, and postharvest longevity. For example, in 'Draper' blueberry fruit firmness was reduced by 16% when internal fruit temperature was increased from 66°F to 77°F (Figure 3) (Wei Yang, unpublished data). In-house bruising assessments can be done to see how different cultivars respond to various cultural practices and harvesting conditions. A step-by-step guide to evaluating blueberry internal bruising (IBD) can be found in the section "How to Conduct an IBD Assessment" on page 9 of this publication.

Additional cultivar traits that determine suitability for mechanical harvest include loose fruiting clusters with fruits that detach easily and cleanly. Loose clusters are particularly important for promoting harvest efficiency. Berries should detach without a wet scar or adhering pedicel (fruit stem), although packing lines can be equipped with de-stemmers making this less of a concern, depending on packing line equipment. Concentrated ripening can also be advantageous if it maintains fruit quality within the cluster and reduces the number of passes a machine needs to make. Cultivars also vary in storability and moisture loss. An ideal cultivar, from a storage perspective, would be one that experiences very low levels of moisture loss and retains quality longer. While this characteristic is important regardless of harvesting technique, it is especially important for mechanically harvested fruit that experience more agitation.

Proper plant architecture is also essential for efficient harvesting that minimizes ground loss and plant damage (Figure 4). Plant height and width should be maintained to allow the harvester to pass over the plant without causing damage. A narrow crown will permit the catching plates that are used on many over-the-row harvesters to fit tightly around the bush, minimizing gaps that fruit could fall through (Figure 5) (Rohrbach and Mainland 1988). Canes that are upright, as opposed to low hanging or drooping, are preferred, because they fit better within over-the-row harvesters. However, canes with a high crop load will naturally droop. Therefore, pruning and trellising should be done to ensure the plant canopy is spatially manipulated for optimal machine harvest without sacrificing yield. Grow tubes may be used to modify bush architecture and can promote a more upright architecture by reducing crown and root dry weight while increasing the aboveground to belowground dry weight ratio (Tarara et al. 2014; Strik et al. 2014). Some growers use milk or juice cartons as replacements for grow tubes.

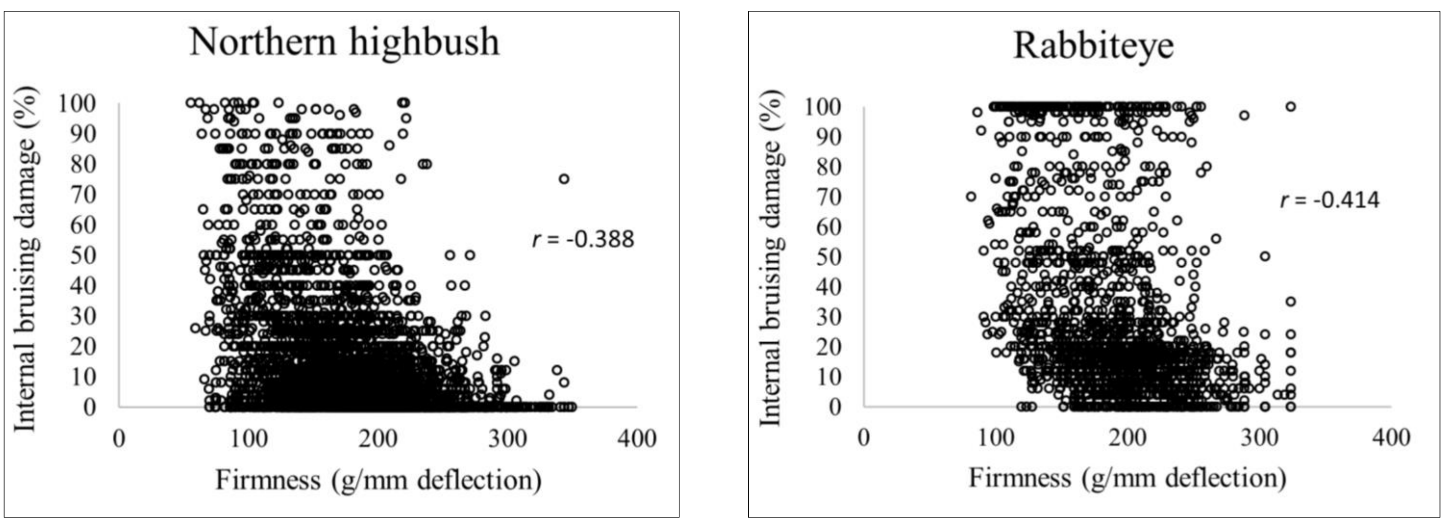

Figure 2. Internal bruising is poorly correlated with firmness among eleven northern highbush cultivars (*left graph*) and three rabbiteye cultivars (*right graph*). In both examples, the Pearson correlation coefficient is less than 0.50. These data show that firmness is not necessarily related to incidence of internal bruising. Some fruit may measure firm but actually have internal bruising and will later soften in storage. Unpublished data provided by of Wei Yang.

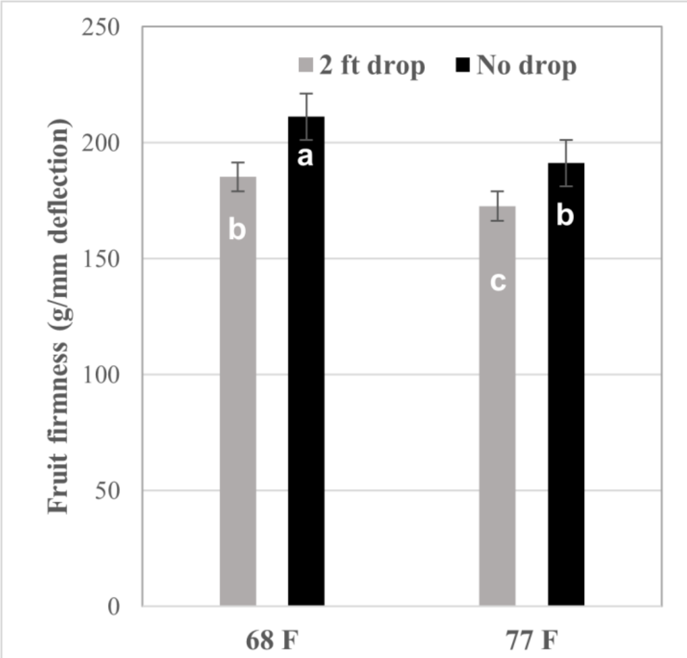

Figure 3. Effect of fruit internal temperature on 'Draper' fruit firmness. Berries were dropped onto a polycarbonate surface from two-feet high or not dropped (control) when internal temperature was at 68°F or 77°F. Higher temperatures led to more softening, which was measured through reductions in firmness. Note that fruit firmness values with the same lowercase letter are not statistically different (α=0.05). Unpublished data provided by Wei Yang.

Figure 4. Ground loss results from poor fits between blueberry bushes and catch plates on the machine harvester. Photo by Lisa DeVetter.

Planting/Field Design

Fields that are intended to be machine picked should be designed with considerations for the harvester. Posts that may be used for trellising should be of a height that a machine can pass over or around. Risers used for irrigation, chemigation, or cooling should also be low enough so that they are not damaged by the pass of a harvester. There should also be adequate spacing at the ends of fields so a machine can turn around and navigate as needed. In fields that are to be handpicked, row breaks are placed every 300 to 400 ft to minimize walking to the weighing station. Row breaks are less important in fields that are to be machine harvested and their need is based on the loading capacity of the harvester. Alleyways planted with perennial grasses or other cover crops can reduce soil compaction and will also dry out faster if there is rain. This lessens the potential for deleterious soil health impacts and the risk of a harvester getting stuck after a significant rainfall event.

Figure 5. Crowns that are pruned to be narrow (*top photo*) permit catch plates that are on many over-the-row harvesters to fit tightly (*bottom photo*), minimizing gaps that fruit could fall through and reducing ground loss. The bottom photo shows a perfect seal around the end posts and small plants with a narrow crown. Photos by Lisa DeVetter (top photo) and Fumi Takeda (bottom photo).

Raised beds optimize the fit of catcher plates around the plant and also have an important role in reducing ground loss. Ground loss results when detached berries are not captured by the catching surface and fall onto the ground. To avoid ground loss, growers should establish fields and maintain the width of raised beds to no wider than the lower entrance of the machine harvester. The standard dimension of a raised bed is 12 to 18 in. high and 4 ft wide at ground level, with rows spaced 10 to 11 ft apart, center-to-center, to accommodate farm equipment, including harvesters. Establishing straight rows is important to accommodate harvesters without auto-steering capability.

Trellising is recommended for machine harvesting fresh and processed fruit, with benefits greatest among cultivars that lack upright canes. Trellising has been shown to improve hand- and machine-harvest efficiency while reducing ground loss (Strik and Buller 2000). A standard trellis system consists of metal or wood end posts, adjustable crossbars, and two 12-gauge galvanized, high-tensile wires. Standard spacing of line posts is 20 feet apart, and strong tension should be maintained to support crop load. Cross bars will need to be raised as plants mature and increase in height. Most trellis systems are installed one to two years after planting.

Pruning and Training

Balanced pruning is important regardless of the destined market. Proper pruning will ensure sustained yields of high-quality fruit and should be done with an understanding of cultivar growth habits and production goals. For machine harvesting, plant age and vigor should also be taken into account and adjusted as needed. Pruning should create an open center that maximizes light interception into the canopy and harvest efficiency. Aim to have fruiting wood oriented near the outside of the bush to promote easy access by a harvester. Fruit in the interior may not be accessible or may drop through gaps among catching plates, leading to ground loss.

Growth that is outside of the trellised area or too wide may not fit inside the throat of a harvester. Branches that are too wide are also prone to having fruit knocked off by other field activities, like spraying and other equipment work. Abrasions or plant damage can also occur, which creates portals for disease entry and reduces harvest efficiency (Figure 6). Pruning should be done to maintain good picking height, which is influenced partially by the cultivar.

To further optimize pruning and training for machine harvest, keep the crown narrow and remove low growth below the catcher plates to ensure a good fit of the catcher plates around the base of the plant (Figure 5). This should ideally be done starting at establishment but can be done in an established field that is being transitioned to machine harvest by selectively removing canes over time. Trellising should aim to position canes and branches upright so they fit better within a machine. The extent of trellising will vary based on the cultivar, age of the plant, and plant vigor.

Figure 6. Abrasion and breakage of branches and canes can occur if plant architecture is not compatible with machine harvesters. Photo by Lisa DeVetter.

Harvest

Field Preparation and Management

Field preparation for machine harvest of fresh market blueberry begins with practicing good pest and disease management, including birds, throughout critical periods. Fungal infections or feeding activities can lead to soft fruit or puncture wounds. This can result in fruit juice leaking onto otherwise clean berries, which can worsen postharvest decay. It is important to remember hand pickers can be more selective and avoid harvesting unsound fruit, while a machine harvests every fruit. Therefore, it is particularly important to manage pests and diseases for machine harvest. Preharvest, clean-up sprays may also be done to eliminate fungal spore loads and insect contaminants. As always, attention needs to be paid to preharvest intervals.

Weeds should also be managed as they compete with the crop for nutrients and water. Some weed species or severe infestations can interfere with harvester operation and prevent the catcher plates from fitting tightly around the blueberry plants, resulting in ground loss. Additionally, weeds in rows can release seeds that may contaminate harvested fruit if they are picked up and not removed by blowers before filling harvest containers.

Timing

Determining harvest timing is a delicate balancing act and will depend on market conditions, labor availability, labor contracting, and crop maturity. Fortunately, machine picking requires fewer laborers and so is easier to coordinate, which is one of the primary advantages of transitioning from handpicking to machine harvesting. However, there may be situations where a combination of handpicking and machine harvesting may be more profitable. For example, a first, or "lead," pick that entails handpicking the first, large, blue fruits may enable a grower to enter the market earlier and can provide financial benefits. After a lead pick, the grower may allow the crop to develop further before machine harvesting. In general, a first machine harvest that optimizes fruit quality while minimizing premature harvest of green fruits can be done when 50 to 60% of the crop are blue. Harvesting after this stage may lead to the development of soft, overmature fruits that bruise easily and stores poorly. Overmature fruits may also drop from the bush more easily, contributing to ground loss. The machine harvester should be adjusted to minimize the proportion of green fruits that are picked so that these fruits can be harvested later, once mature. For some cultivars, two to three machine harvests may be required to remove most of the marketable fruits.

The time of day for harvest should also be considered. Temperatures should be cool to maximize fruit firmness and avoid postharvest quality losses. Many grower operations stop harvesting at temperatures greater than 70°F, as fruit softening is a greater concern at and above this temperature threshold. Evening or night time, when temperatures have cooled, may be suitable for harvest, and also early morning as long as dew is not present on the fruit. Harvesting while there is moisture on the fruit should be avoided as it can lower fruit quality. Thus, fruit should not be picked after rainfall until it has dried.

The harvest interval is another means for managing fruit quality. In the Pacific Northwest, a 7- to 14-day harvest interval is generally adequate (Figure 7) (Cai et al. 2021). Harvesting at shorter intervals can increase the amount of green fruits removed and costs associated with harvesting without any significant improvements in firmness. Harvesting at longer intervals can increase fruit softness and diminish resultant quality and storage life. Cultivar and environmental considerations should be factored in, as some cultivars may soften more rapidly at higher temperature conditions relative to others.

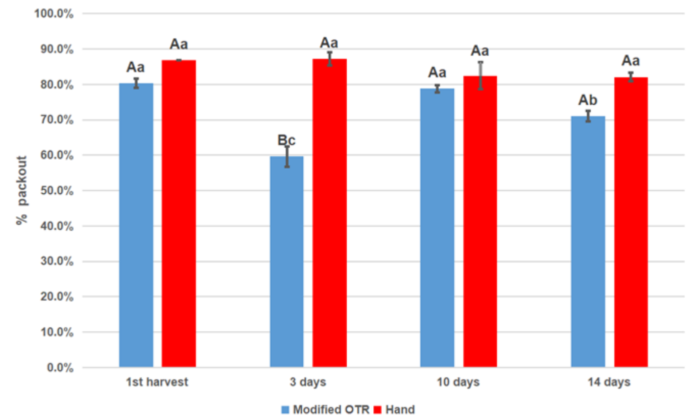

Figure 7. Packout of 'Liberty' northern highbush blueberry harvested by hand or with a modified over-the-row harvester with soft-catch surfaces. The second harvest was 3, 10, or 14 days after the first harvest and correspond to 3-, 10-, and 14-day harvest intervals. Packout was reduced in machine harvested fruits at the three-day interval due to a high proportion of immature, green fruit. Packout was greatest when the second harvest occurred 10 to 14 day after the first harvest. Uppercase letters represent significant differences in harvest interval and lowercase letters represent significant differences due to harvester type (i.e., hand versus machine harvest) (α=0.05).

Harvester Operation

Both harvester operation and harvester technology are important to obtain quality blueberries. It is essential to have a trained harvest operator and crew to maximize the use of the technology. The machine should be centered on the row. On some harvesters, an auto-steer option can keep it centered on the base of each plant. Additionally, harvester height should be set to minimize ground loss and plant damage. If the machine is set too low, catcher plates can scrape the ground and contaminate the harvested crop. If it is set too high, catcher plates will not achieve a good fit around the plant and ground loss will increase. A machine running on the center of the plants and as low as possible reduces ground loss.

The machine settings should be adjusted for the cultivar, maturity, and environmental conditions. Settings to adjust include shaker RPM and amplitude, ground speed, and head gap between rotors. The weight of the shakers can also be adjusted. The shaking heads should be set to remove much if not all the ripe fruits on each pass while minimizing the amount of unripe fruits harvested; this can require several initial adjustments and changes during the season. Additionally, cleaning fan RPM and conveyor belt RPM should be adjusted based on conditions and fruit volume, but running the cleaning fan on the top-loading harvester models at high RPM could cause fruit damage.

Some harvesters can be equipped with technology specifically designed to improve machine harvesting for the fresh market. Harvesters with suspended soft surfaces instead of traditional hard surfaces can reduce fruit impact and internal bruising damage sustained during harvesting. For example, Oxbo Corporation has the Soft Surface Kit that fits onto several over-the-row harvester models and includes molded catcher plates with suspended soft surfaces and additional suspended soft surfaces under the picking heads (Figure 8). Research to date has shown that these soft-catch surfaces in over-the-row harvesters reduce the incidence of internal fruit bruising relative to non-modified, over-the-row harvesters (DeVetter et al. 2019; Peterson et al. 1997; Sargent et al. 2020; Takeda et al. 2017). While these soft surfaces can increase packout relative to non-modified, over-the-row harvesters, fruits still soften more rapidly in storage compared to handpicked berries.

There are new harvesters and harvest-assist machines being introduced by several manufacturers (e.g., Kokan 500S Air Berry Harvester by BSK in Serbia and the Harvy 500 from FineField in the Netherlands) that are intended to reduce internal fruit bruising and replace or augment handpicking. Research on these new harvest technologies and catcher designs is limited and so is not discussed in this publication.

Harvest Containers

Blueberry is generally harvested into flats or lugs. Shallow flats are preferred because they minimize fruit compression. Deep harvest containers or lugs used for berries destined for the processing market are not recommended for fresh market fruits because they can be filled too full (greater than six inches), which may cause softening of fruits at the bottom through compression. A general rule is not to fill flats with more than 17 lb of fruit (assuming a 16 in. by 24 in. dimension).

After flats are filled, care should be taken to stack them correctly. Throughout the process of replacing and stacking filled flats, minimize sudden drops and rolling berries during visual inspection. If harvesting during daylight hours, use a canopy to shade not only workers but also empty and filled flats. A canopy provides shade and prevents heat from building through sunlight exposure. Flat temperatures when placed in full sunlight can quickly reach temperatures of 140°F, which can "cook" harvested berries and cause losses in quality and shelf life. Shading harvested blueberries in flats in the field is highly recommended.

Postharvest Management in the Field

After berries are harvested, it is a race against time to get the fruit into cold storage so the cold chain can begin and be maintained. As mentioned above, if the crop is harvested during daylight hours, keep it shaded or covered to reduce heat accumulation through solar radiation. Shade canopies, empty flats placed on top of full flats, or even reflective covers may help reduce heat accumulation. Avoid letting fruit sit out for an extended duration in the field, particularly under direct sunlight. Consider refrigerated trucks or some form of cold storage to cool fruit rapidly to extend its postharvest quality and longevity.

Figure 8. Harvesters are being redesigned to decrease impact forces that can lead to bruising in order to improve packout and quality for the fresh market. This Oxbo machine (*left photo*) has a Soft Surface Kit (*right photo*) that includes molded catcher plates with suspended soft surfaces and additional suspended soft surfaces over the horizontal conveyor belt on either side of the machine, which improves packout and reduces bruising compared to non-modified, over-the-row harvesters without a soft surface over the hard conveyor belts. Photos by Lisa DeVetter.

Packing Facilities

Refrigeration and Forced Air Cooling

Proper packing facility design and practices can also improve fruit quality. The first step is cooling fruit to remove field heat. Picking at night or early in the morning (as long as dew is not present) can maintain a more favorable berry temperature, but cooling using refrigeration or forced air cooling can be a great asset. Forced air cooling reduces internal berry temperatures rapidly and should be done in combination with good postharvest management practices in the field, such as avoiding harvest activities during high-temperature conditions and leaving fruit in the field for too long.

Sorting Technologies

There have been many advancements in sorting technologies. Sorters can detect softness and color defects, such as green and red fruits. However, there is no commercial sorter at this time that can detect internal bruising. Softness and bruising are not equivalent. Although optical non-destructive techniques for bruise assessments exists for laboratory use (Li et al. 2019), the technology for sorting blueberries based on internal bruising damage has yet to be developed for commercial blueberry packing lines. Therefore, a soft sorter cannot sort fruits by bruise damage. This is partly because bruising can take time to develop and may not be detected by changes in firmness at the time of packing. Furthermore, even if a bruise results in softness at the time of sorting, this softness tends to be localized and can escape detection if not in contact with the soft fruit sorter contact plate(s).

Despite the limitations of sorters, they are still powerful tools in a packing facility. Good operators and packing line design allow the technology to function optimally. The number of people sorting should be carefully considered and discussed with the manufacturer. Having multiple sorters adds to initial costs but in return may lead to a higher quality packout. Recently, more advanced sorting lines have become available that eliminate the need for hand sorting, though they do cost more. A good packing line design should minimize fruit drop (ideally, less than or equal to six inches) and roll. Padding and foams can be used to reduce impacts at drop points but need to be carefully considered. Soft padding and foams can form biofilms that are difficult to clean, which can increase the risk of microbial contamination, creating a food safety concern. Also, some certifiers only allow certain types of materials on lines, so it is important to check if there are material restrictions for particular packing lines.

Automated Dumpers and Flat Conveyance Systems

One of the most important locations along a packing line is the hopper. Fruit should be gently transferred from flats to either hoppers or the conveyor belt. If possible, fruit should be carefully rolled into hoppers or onto conveyor belts to minimize the potential for drops that can result in bruising. Hoppers should not be overfilled, which can cause compression and damage berries. Automated dumpers and flat conveyance systems can help reduce the human tendency to overfill hoppers and allow consistent, gentle transfer of fruit directly onto packing lines, thus eliminating the need to have a hopper.

Setting Quality Standards

Expectations on the final packout should be adjusted for machine-harvested fruit. Despite technological advancements, machine harvesters still do not have the selectivity and gentleness equivalent to a well-trained hand harvest crew. Depending on the cultivar, about 30–80% of fruits harvested by machine with a soft catch system have no visible internal bruising damage, while more than 85% of fruits picked by hand are without internal bruising (Figure 1) (Sargent et al. 2021).

As a result, packing lines may need to be more aggressive with removing fruit that does not meet standards of quality in terms of color and firmness. While blueberry growing and sorting operations may be reluctant to do this because of lost revenue concerns, it is also important to consider the cost savings that may be realized by relying less on hand harvest labor and more on mechanized systems.

Food Safety

Harvesting Containers and Flats or Lugs

The physical and hygienic conditions of the harvesting containers are extremely important for maintaining the microbiological quality and extending the shelf life of harvested fruits. Growers should select a type of harvesting container that is easy to clean. Before each use, the containers should be inspected, and those with physical damage should not be used. If disposable liners are not used, flats and lugs used for machine harvest should be cleaned and sanitized after each use. Most packing plants use automatic washing machines to clean the flats and lugs. Cleaned and sanitized containers should be dried thoroughly before being used again. Commercial cleaners and sanitizers have different efficacies. Growers are encouraged to select those that can more effectively remove soils and harmful microorganisms from harvesting containers. The containers should not be placed at any time on the ground during harvesting. During the offseason the containers should be stored indoors and off the floor in a clean and dry environment. Furthermore, the containers should be used only for harvesting purposes; they should not be used to store chemicals or collect trash.

Machine Harvesters

Machine harvesters could be a source of physical, chemical, and microbiological contamination. Therefore, the equipment should be kept in good condition and have the necessary maintenance performed before the season starts. Routine cleaning and sanitation are important; the equipment should be properly cleaned and sanitized after each use and allowed to completely dry before the next day's harvest.

Fruit Quality

Hand pickers should only harvest fruits of good quality, and sorters on the line of the mechanical harvester should discard poor-quality fruits. Fruits with physical damage or visible signs of contamination (e.g., mold, bird droppings) should be discarded. Fruits dropped on the ground should be discarded.

Employee Hygiene

Field toilets and handwashing stations should be made available for employees. All employees should wash their hands before starting work, after using the bathroom, before and after lunchtime break, and after contact with contaminated areas or surfaces (e.g., after touching one's face, after eating or smoking, after touching any surfaces that are not regularly sanitized).

Storage

Provision of cold chain through adequate postharvest storage facilities that reduce decay, bruise development, physiological breakdown, and dehydration contributes towards maintenance of fruit quality. Cold room temperatures should be maintained at 32 to 34°F with high relative humidity (greater than 95%). A controlled or modified atmosphere can also be a good option with 10 to 12% CO_2 and 1 to 3% O_2. These parameters may require further adjustment depending on cultivar. Decay may be reduced through use of liner bags, UV light exposure, ozone treatment, or fumigation with SO_2, but these methods are still being developed and investigated.

Internal Bruise Assessment

Fruit internal bruising damage (IBD) is caused by various external impacts on the fruit surface, which leads to damage in the cell membrane and leakage of water and other cellular contents. Initially, the only visible sign of impact damage is localized loss of firmness in the affected area and water-soaked tissue. Damaged membranes cannot keep their cellular constituents compartmentalized, allowing oxidative enzymes to react with phenolic compounds, which results in damaged tissues becoming dark. IBD in machine-harvested fruits begins to develop immediately after impact. Over several hours, the water-soaked area, which is usually wedge-shaped, darkens and can be visualized.

Researchers and some packers assess IBD by visually estimating the amount of discolored, often wedge-shaped areas of pulp under the peel as a percent of the sliced surface area (Figure 1). Given blueberries can be impacted at different parts of the fruit, impact damage that occurs around the equator or calyx end will appear quite different when sliced through the equator of the fruit. When the impact damage occurs on the shoulder of the fruit, slicing through the equator for bruise visualization reveals a circular zone of darked tissue. In contrast, when the impact occurs at or near the equator, slicing through the equator will reveal bruise damage in a more or less wedge-shaped, darkened area. If the fruit is impacted either at the stem or calyx end, slicing the fruit through its equator cannot be used to visualize damage unless the impact damage has expanded to the middle of the fruit and just the top of the impact damage becomes visible. For these reasons, the method of slicing fruit along the equator for IBD visualization underestimates the extent of full impact damage.

Despite the drawbacks to this method of IBD visualization and assessment, it is still widely used by researchers and some packers. This method has been used for the last 30 years and is relatively simple, requiring just a razor blade and a cutting board. Researchers typically determine IBD by visually assessing four sets of 50 randomly selected fruits, and each set of 50 berries is organized on a cutting board with 50 premade dents (Figure 9).

How to Conduct an IBD Assessment

The suggested method of slicing berry samples is to cut berries perpendicular to their stem and calyx axis on the board then visualizing the fruits for bruise damage.

1. Use a sharp razor to obtain clean-cut surfaces along their equatorial axis to reveal two halves of the fruit sliced through the equator. The dents on the tray help keep the two berry halves stable and together.
2. Visually evaluate each berry to estimate the IBD percentage of the cut surface area of each berry. IBD can be quickly estimated as no bruising and 1–5% IBD. However, IBD assessment will take longer to accurately estimate 5–10%, 10–20%, and greater than 20%, even for trained evaluators.
3. Record IBD percentages for each of the 50 berries and record the number of berries with no IBD.
4. Repeat the process for the other three sets of 50 berries.
5. Finally, calculate the average IBD percentage and the percentage of berries without IBD. Packed fruits exceeding an IBD of 20–25% should not be cold stored for more than two weeks (Brown et al. 1996).

Figure 9. Internal bruise damage can be estimated visually by assessing four sets of berries (50 berries per set) placed on a flat tray or cutting board with 50 premade, shallow indentations (*top photo*). Berries are sliced through the equator (perpendicular to the stem/calyx axis), placed on the board, and bruising is estimated for all berries (*bottom photo*). Photos by Wei Yang.

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Yang, W. n.d. Oregon State University.

By
Lisa W. DeVetter, Associate Professor, Washington State University
Wei Q. Yang, Associate Professor, Oregon State University
Fumiomi Takeda, Research Horticulturist, United States Department of Agriculture Agricultural Research Service
Jinru Chen, Professor, University of Georgia

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