

DETERMINING FRUIT MATURITY

Apple Maturity Indices

To allow time to schedule labor, growers must estimate optimum harvest dates well before picking fruit. In addition, there are different optimum maturity levels for the same cultivars, depending on intended use and storage life desired. Harvesting too early results in fruit that is off-flavor or lacking flavor, poorly colored, small, and subject to bitter pit and storage scald. Leaving fruit on the tree too long results in softer fruit, the potential development of watercore, and a shorter storage life.

The obvious first step in marketing a high-quality product is to *grow* a high-quality product. Early tree training, annual pruning, proper fertilization, and sound pest management can greatly affect tree vigor and, thus, fruit condition. Light crops, crops from extended bloom periods, or crops with high nitrogen levels may differ markedly in maturity date and subsequent storage potential. Each block and cultivar or strain should be evaluated separately for its maturity and storage potential.

Within the list of maturity indices (starch, firmness, juice sugar and acid content, seed color, flesh color, presence of watercore, background color, and internal ethylene concentration [IEC]), there is a priority order for making decisions. Identifying the targeted consumer is the first decision to make. Will the harvested fruit be made available for immediate fresh market consumption, future fresh market consumption following regular or controlled atmosphere storage, or is the fruit destined for the processor? Once the targeted consumer is identified, the relative importance of the specific maturity indicators will be known. With the exception of IEC, which involves the use of a gas chromatograph, all these indicators are relatively easily measured.

Of all the indicators, background color, starch content, and firmness are the most important factors in guiding harvest timing. They are correlated to some extent with sugar content, acidity, flavor, aroma, texture, IEC, and potential storage life. If a fruit lacks the characteristic background color of a specific variety, obviously it will be difficult to sell as a fresh market item. A fruit harvested without desirable color will not change significantly during storage. Fruit lacking characteristic background color is most likely going to be firm, starchy, and immature. The only viable outlet for such fruit is most likely the processing market. However, fruit destined for processing also has minimum maturity standards. Fruit with low starch readings of 1–2 on an index of 1–8 are still immature and will lack flavor and sugar content. They will have a desirable firmness, but the flavor aspect will overshadow this. In general, a combination of the presence of background color, starch conversion of 25–35 percent, and firmness above 15 pounds will qualify for a good storage or processing candidate. For immediate consumer consumption, the presence of background color, starches in the range of 4.5–6, sugar content above 13%, and firmness readings greater than 13 pounds should meet consumer expectations.

Before doing any measurements, collect a representative sample of fruit. Choose five to eight trees per block per cultivar and rootstock that are typical of the trees in the block, and care-

fully mark them so that you can collect weekly samples. Trees should have a uniform crop load and be of uniform vigor. Begin sampling approximately 4 to 5 weeks before normal harvest is anticipated. Sample four fruits from the periphery of each tree (recognizing that this represents the most mature fruit on the tree), selecting fruit that is free of any visible insect injury or disease damage. Fruit temperature can affect certain test results; therefore, measurements of the samples' maturity should be performed within 2 hours of harvest.

Days after full bloom (DAFB)

DAFB should be used as a general reference to indicate when fruit might mature. There may be a 5- to 20-day spread between the average harvest date and the optimum harvest date for a particular cultivar. Record full bloom by block and cultivar each spring, since full bloom may vary from one site on your farm to another. Estimated days from full bloom to harvest for some cultivars are listed in Table 1-6. These dates should be used as general guides and can vary from year to year.

Fruit firmness

Fruit firmness can be measured with either an Effigi fruit tester or a Magness-Taylor pressure tester. Both work on the principle that fruit flesh becomes softer as it matures. Many factors, including watercore and fruit size, can affect firmness readings. The presence of watercore will give higher readings that are inaccurate. Therefore, discard firmness measurements of apples that have watercore. Large apples are usually softer than smaller ones, so for firmness measurements try to choose apples of a relatively uniform diameter and that are representative of the fruit in the block.

The most critical feature of firmness testing is the speed with which you apply force to the plunger. The proper speed is about 2 seconds, and to regulate your speed you might say to yourself, "one, one thousand, two, one thousand" as you insert the plunger into the fruit. Applying pressure too fast is probably the most common way of getting a false reading.

For apples, use the 11 mm tip supplied with the pressure tester and penetrate to a depth of 7.9 mm as marked on the plunger. Test each apple on both the blush side and the nonblush side, then average both readings.

Percent soluble solids (or sugar levels)

As fruit matures, starch is converted to sugars. To measure the percentage of Brix, or sugar, in a solution, a refractometer can be used. As fruit matures, refractometer readings increase, indicating fruit maturity is progressing.

Fruit from trees with a heavy crop will have lower readings than fruit from trees with a light crop under similar growing conditions. Sugar content will be higher in years of reduced moisture availability, high temperatures, and high sunlight. As with firmness, refractometer readings will also vary by fruit position within the tree and nutritional status. Fruits located in exposed areas, where considerable photosynthesis is taking place, have higher soluble solids. Fruits heavily shaded and located inside the tree or on weak spurs have the lowest soluble level of fruit on that tree.

A refractometer can be purchased for around \$200 from a number of sources. (Refer to the buyer's guide in each July issue of *American Fruit Grower*). Measurements are made by squeezing a small amount of juice from the fruit onto the prism of the refractometer. A small garlic press works well to produce the juice. Hold the instrument up to the light and read the percentage of soluble solids by looking through the lens. After each sample of juice, rinse the prism face off and wipe with a soft tissue to avoid contamination among samples. One can calibrate refractometers by zeroing with distilled water and at 10 percent with a solution of 10 grams of sucrose dissolved in 90 grams of water. More expensive (~\$600) digital refractometers can be purchased from scientific supply companies such as Fisher, VWR Scientific, or Thomas. Digital refractometers indicate the percent dissolved solids to the nearest 0.1 percent.

Acidity

As fruit mature, their acid content decreases. Malic acid is the major acid in apple juice, and it plays a major role in the flavor attribute. Table 7-3 categorizes several varieties of apples based on their sugar and acid content. Granny Smith apples have developed a well-known image based on their tart or acidic flavor. Some apple varieties, such as Pink Lady, attain acid values as high as 1.4–1.5% in juice. There are no guidelines for maturity based on acid level. The amount of acid present is related to the variety and maturity stage. A drop in acid level is an indicator of advancing maturity. Measuring acidity is somewhat cumbersome and involves the use of common laboratory instruments such as a titrator or a buret. For best use as a maturity indicator, acid level should be recorded over a number of harvests to develop patterns and guidelines.

Starch levels

Stage of maturity can also be assessed by performing the starch-iodine test to document starch disappearance. Applying an iodine solution to the cut surface of fruit stains the starch a blue black. The iodine solution can be made by dissolving 10 grams of iodine crystals and 25 grams of potassium iodide in 1 liter of water. The pattern of starch disappearance is specific for each variety. Delicious loses its starch in a fairly even ring, while Golden Delicious shows an uneven pattern.

Preparing a starch-iodine solution

Always use freshly prepared solution at the beginning of every season. The solution is sensitive to light and should be stored in a dark container. A darker colored bottle or glass jar wrapped in aluminum foil will suffice. Chemicals needed for this test are potassium iodide and iodine crystals. Check with your local pharmacist for the iodine. (Note: As part of Homeland Security, iodine can only be purchased in small quantities.) The iodine solution can be made by dissolving 10 grams of iodine crystals and 25 grams of potassium iodide in 1 liter of water. The pattern of starch disappearance is specific for each variety. Delicious loses its starch in a fairly even ring, while Golden Delicious shows an uneven pattern.

Warning: Iodine is a very poisonous chemical. The iodine solution should be properly labeled and kept away from children and pets. Apples used in the test should not be fed to any animals or used in composting. In case of ingestion of iodine or iodine-

treated apples, induce vomiting and consult the Poison Center Hotline immediately.

Wilson Irrigation Supply in Washington sells starch-iodine solution already made. Visit them online at <http://www.wilsonirr.com/> or call them at 1-800-232-1174.

Fruit used for firmness testing and soluble solids readings can also be used for the starch-iodine test. Cut the fruit at right angles to the core, approximately halfway from the stem to the calyx end. Apply the iodine solution to the cut surface, drain away any excess, and rate the fruit after 2 minutes. The reaction of iodine and starch is temperature-dependent. Under cold conditions, the reaction will take longer. An external heating source will speed up the reaction in cold environments. Avoid contact and be cautious when mixing and applying iodine solution. Test a minimum of 10 fruits per block, preferably 20. A commonly used rating system is a scale of 1 to 6, as follows:

- 1 = full starch (all blue-black)
- 2 = clear of stain in seed cavity and halfway to vascular area
- 3 = clear through the area including vascular bundles
- 4 = half of flesh clear
- 5 = starch just under skin
- 6 = free of starch (no stain)

In Washington State, general guidelines have been established for using this scale to rate the long-term storage potential of Delicious and Golden Delicious: a 1.5-2.0 rating and a 2.0-3.0 rating, respectively. Growers should develop scales of their own for their varieties and growing conditions.

Another good reference for starch testing is "Predicting Harvest Date Windows for Apples" by G. D. Blanpied and K. J. Silsby, Information Bulletin 221, Cornell Cooperative Extension (order from Resource Center, Cornell University, 7 Business and Technology Park, Ithaca, NY 14850). This publication contains a Generic Starch-Iodine Index chart that is an excellent picture guide for making starch index determinations. It is also available online at <http://ecommons.library.cornell.edu/bitstream/1813/3299/2/Predicting+Harvest+Date+Window+for+Apples.pdf>.

Seed color and fruit color

Seed color can also be used in a general way to determine maturity. Cut the fruit in half and rate the seed color on the following scale:

- 1 = clear (no color)
- 2 = trace (tips brown)
- 3 = 1/4 color
- 4 = 1/2 color
- 5 = 3/4 color
- 6 = full color

The test probably works best for early-maturing varieties.

Flesh color can help determine the amount of chlorophyll still present in the apple. Take a 1/16- to 1/8-inch-thick slice from the middle of the fruit. Hold the slice up to a bright light and observe the extent of green (chlorophyll) in the flesh. Again, a rating of 1 to 6 can be used:

- 1 = flesh all green
- 2 = some loss of green from center of fruit
- 3 = heavy green band 1/2 inch thick under skin
- 4 = heavy green band 1/4 inch thick

5 = heavy green band 1/8 inch thick

6 = green essentially gone from under skin

Fruit texture

Texture can be evaluated by a simple taste test. If, as you chew the fruit, the flesh tends to wad up or seem cottony, the apple has not reached an ideal stage for harvest. This is a subjective test and probably no two people will always agree.

New technology is being developed for nondestructive assessment of firmness or texture by companies in Israel (Eshet Eilon), The Netherlands (Aweta), and the United Kingdom (Sinclair). The technologies work on the principle of acoustical vibration, or the amount of elasticity of the fruit following impact by nondestructive tapping of the fruit surface. With acoustics, it has been shown that consumers are able to differentiate fruit based on the acoustical properties as measured by an electronic instrument that taps the fruit and calculates an index based on the fruit's weight and vibration frequency. Bench-top models have been developed. The goal of these companies is to automate the systems for use on packing lines to assess fruit texture at a rate of up to 10 fruit per second.

Remember, harvesting fruit at its optimum maturity requires skill and experience. Do not rely on just one maturity test, but try to use several different tests each year.

Pear Maturity Indices

Pear maturity indices are not as reliable or consistent as those used for apples. Indices similar to those used for apples historically have not been as consistent for different years or orchards. The exception is firmness and possibly days after full bloom.

A combination of two or more of the following indices will give a better indication of fruit maturity. As with any measurement used to predict fruit maturity, expect variations from year to year, block to block, and by tree and growing conditions. The best method is to select several tests and repeat them every year to develop a track record for your orchard.

Days after full bloom (DAFB)

DAFB can give an approximate harvest date or a "ballpark guess." The major problem with this type of measurement is that there is little consistency from year to year and a wide range in suggested DAFB values. For example, for D'Anjou the range can be 120-150 days, for Bartlett 110-133, for Bosc 130-145, and for some of the new Asian pears 112-150. Firmness in pears can be measured with the same device as apples, but with an 8 mm tip to a depth of 7.9 mm

Firmness

In pears, fruit firmness is probably the most reliable indicator of maturity. Fruit to be sold immediately or held only for a short time can be harvested at a much softer stage than fruit to be stored for a longer time. Firmness is not a good indicator of maturity for Asian pears. These types are best when ripened on the tree where fruit pressures will run 8 to 12 pounds. Color and taste are better indices for the Asian types. The recommended ranges for firmness measured by a pressure tester are as follows: D'Anjou 13-15 pounds, Bartlett 15-17 pounds, and Bosc 14-16 pounds.

Fruit appearance

Although it is a subjective evaluation, fruit color and finish can be a valuable maturity indicator. In Bartlett, look for a change from green to a white green, blotchy appearance at the fruit neck and finally a light yellow. Any pink coloration at the calyx end probably indicates a premature ripening problem in Bartlett. For D'Anjou, look for a change in ground color. Russeted Asian pears change from green to brown to orange or gold. Yellow-fruited varieties change from grass green to light green to yellow green.

Fruit finish is another means of judging maturity. For D'Anjou and Bartlett, look for smooth, waxy skin. As the fruit matures, corking of the lenticels is related to fruit maturity. An immature fruit has white lenticels that become brown and shallow. The brown color in lenticels is a good indicator that the fruit will ripen without shriveling.

Other methods

Amount of soluble solids is often not a good indicator of maturity in traditional varieties because of the need to harvest the fruit before it is ripe. A minimum of 11 percent for Bartlett and of 10 percent for all other varieties is recommended, except in Asian pears, where 12 percent is recommended.

Measuring the amount of starch in fruit is a "new" technique that has worked very well for apples but only with limited success for pears. As the fruit matures, starch is converted to sugars. Reports from the Pacific Northwest indicate that the starch iodine test may be a reliable indicator and that fruit should be harvested when 60 percent of the cut fruit surface still contains starch.

HARVESTING FRUIT

Bruising in Fruit

Fresh-market fruit growers have long been concerned about bruising. Processing-fruit growers also have grown concerned, because unbruised fruit commands the best prices. The vast majority of bruising in the harvest process falls into two categories: 1) picking bruises associated with rough handling and detrimental impacts, and 2) compression bruises associated with significant vibrations during transport.

Bruising is an ever-present problem. One study showed that bruising of fruit after harvest ranged from 0.6 to 13 percent, with an average of 7.1 percent. A study conducted of packing sheds indicated that bruising caused 8.1 percent of the culls, while another study found bruising to cause only 2.7 percent of the culls. At the retail level in supermarkets, bruising was found to range from 29 to 78 percent, averaging 61 percent.

While bruising is a concern, it must be regarded as a defect that can be controlled through basic management principles. We encourage growers to determine the quality of the product being produced and to determine the dollar value of defects in the product. Good management practices then dictate that production steps be modified if the cost of correcting the problem is less than the cost incurred by defects in the product.

Damage inflicted on fruit is related to the energy available for bruising and the characteristics of the product. The energy available for bruising is in turn related to: