Postharvest quality in fresh market stone fruits

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SUMMARY - Postharvest quality in stone fruits is ultimately defined in terms of consumer satisfaction, and includes appearance, texture and flavor, and nutritional value and safety. These result from all decisions and practices beginning with site and cultivar selection, and extending through cultural practices and all stages of postharvest handling. The development of high quality fruit is influenced by such cultural practices as mineral nutrition, irrigation, tree training, pruning and fruit thinning. Harvest maturity is of special importance because of the detrimental effects on quality of harvesting at either too low or too high a maturity, and low maturity harvest is not a solution to long distance marketing. Fruit deterioration, from such factors as fruit rotting organisms, water loss, mechanical bruising and physiological disorders, will adversely impact quality in the market. Of special concern is the need to rapidly cool stone fruits and maintain them near 0°C throughout marketing. Only by attention to all aspects of production and postharvest handling can high quality be achieved and protected in fresh stone fruits.

Key words: Appearance, flavor, nutrition, deterioration, maturity, handling, temperature.

RESUME - *"Qualité post-récolte chez les fruits à noyau commercialisés en frais". Chez les fruits à noyau, la qualité des fruits se définit en terme de satisfaction pour le consommateur. Elle inclut l'aspect, la texture, le goût, la valeur nutritionnelle et un aspect toxicologique. Elle résulte d'une série de décisions pratiques commençant avec le choix du site, de la varieté et du type de fruit. Elle est influencée par les pratiques culturales telles que la nutrition minérale, l'irrigation, le mode de conduite, la taille des arbres et l'éclaircissage. Elle dépend enfin de la récolte et du suivi post-récolte. L'état de maturité à la récolte revêt une importance particulière à cause des effets négatifs induits par une récolte trop précoce ou trop tardive. De plus après récolte il faut protéger les fruits des dégradations liées aux pertes en eau, aux contusions, aux désordres physiologiques ou aux développements mycéliens. Pour ce faire il convient de les refroidir rapidement et de les maintenir à des températures proches de 0°C tout au long du circuit de commercialisation. C'est seulement en s'attachant à tous ces aspects de la production et du traitement post-récolte qu'une bonne qualité peut être obtenue et préservée dans les fruits à noyau.*

Mots-clés : *Apparence, goût, nutrition, détérioration, maturité, traitement, température, fruits à noyau, qualité, post-récolte.*

In recent years the production and fresh marketing of stone fruits (apricots, cherries, nectarines, peaches and plums) has increased rapidly. This has been due in large part to successes in achieving long distance transport to receiving markets. While some movement of southern hemisphere stone fruits to northern hemisphere markets has occurred for many years, only in recent years have these fruits become available worldwide through much of the year. The marketing successes have resulted from a combination of new cultivars and improvements in fruit handling and distribution.

If the volume of shipments is to continue or increase, greater attention must be given to the production and protection of high quality stone fruits. The California industry has seen increasing demand in the US for high maturity fresh stone fruit. Special packing has been developed to supply this premium market, but the handling requirements limit the volume available. This has caused both the industry and University researchers to evaluate the potential for improving the quality (and hopefully advancing the maturity) of fruits packed in large volume operations. To achieve this, all aspects of fruit quality must be explored. This paper reviews some of the recent work in California, and draws upon information summarized in LaRue and Johnson (1989) and reports of more recent studies.

Defining quality

How stone fruit quality is defined depends upon each individual's concerns and viewpoint. People's perception of quality will change as the fruit pass through various stages of production, distribution and consumption, and will be more and more affected by the distribution system itself. Appearance, flavor and consumer satisfaction will remain important, but with prolonged handling they may be increasingly influenced by results of abuse: bruising, shrivel, internal breakdown, fruit rotting, etc.

Factors in stone fruit quality

Important stone fruit quality factors are those which influence external and internal appearance, flesh texture, flavor balance, and nutritional value, as shown in Table 1.

Deterioration problems influencing quality

These stone fruits as a group typically have a relatively short postharvest life (Mitchell and Kader, 1989a). They can quickly pass from ideal ripeness to over-maturity, depending in part on temperature and handling exposures. They will readily lose water and shrivel (with stem browning in cherries), as a result of movement of water vapor from the fruit to the environment, depending upon surface characteristics of the fruit, relative humidity, air velocity and temperature. They can be quickly destroyed by fruit rotting organisms, depending upon the level of inoculum, surface wounds from handling, fungicide treatment and temperature. All except cherry can also become unmarketable as a result of internal breakdown, a chilling injury problem that develops in many cultivars, depending in part upon harvest maturity, temperature and holding duration.

Table 1. Quality factors of importance in stone fruits

External appearance	Background color Amount and brightness of overcolor or red blush Fruit size, shape and smoothness Presence of defects, injuries and disease
Internal appearance	Flesh color and uniformity (characteristic of cultivar) Presence of translucent or brown flesh or stone cavity Overall impression of juiciness
Flesh texture	Melting flesh, not stringy Juicy, not dry, mealy or leathery
Flavor	Sweetness (soluble solids concentration [SSC]) Balance (soluble solids/acid ratio) Characteristic flavor volatiles Astringency (tannins) Objectionable flavors (e.g. acetaldehydes or alcohols)
Nutritional value and safety	Levels of calories, vitamins, minerals and fiber Freedom from toxins from any source

Pre- and postharvest determinants of quality

Many factors influence the quality of stone fruits. While postharvest horticulturists have generally focused on harvest maturity as their starting point, many earlier decisions will profoundly influence the postharvest performance of the fruit. Some of these decisions even predate orchard planting, such as location (climate), site (soil) and cultivar selection. A number of preharvest cultural practices can influence postharvest quality and performance. There are also many handling practices during harvest, packing and distribution that affect quality, as well as the deleterious effect of various fruit deterioration problems.

Effects of cultural practices on fruit quality

The studies and observations discussed here relate to stone fruit production in California. The central valley of California, where most stone fruits are grown, is characterized by a Mediterranean climate, with hot, dry summers. Stone fruits are grown under summer irrigation, primarily in deep, alluvial soils.

Mineral nutrition

Research over the last 10 years has established that peaches and nectarines should be kept between 2.6 and 3.0% leaf nitrogen (N) for best fruit quality. N deficiency leads to small fruit with poor flavor and unproductive trees. Conversely, Michailides *et al.* (1992) have demonstrated many negative effects from excessive N levels.

Response of peach and nectarine trees to N fertilization is dramatic; high N levels stimulate vigorous vegetative growth, shading out of lower fruiting wood, and adversely affecting fruit quality. Fruit maturity is delayed, percent red coloration is decreased, and fruit size is not increased as compared to optimum N levels. Heavily fertilized trees have also been observed to be more susceptible to brown rot *(Monilinia fructicula)* and various insects and mites. Although high N trees may look healthy and lush, excess N does not increase fruit size, production or SSC.

Current research is evaluating sources of N other than commercial fertilizers. Preliminary results indicate that some materials which increase soil organic matter (composts, manures, cover crops, etc.) may improve some aspects of fruit quality, such as SSC, firmness and insect and disease resistance.

Foliar sprays

We have little detailed research on foliar sprays which supply small amounts of mineral nutrients. However, our observations and reports in the literature suggest that these sprays have little effect on fruit growth or quality. Recent research by Crisosto *et al.* (1993) suggests that these sprays should be treated with caution, since their heavy metal content (Fe, Al, Cu, etc.) may contribute to fruit skin discoloration.

Our recent work with two commercial Ca foliar sprays on peach and nectarine (applied every 14 days, starting 2 weeks after full bloom and continuing until one week before harvest) showed no reduction in skin discoloration or increase in fruit quality of mid- or late-season cultivars. Also, these foliar sprays did not affect fruit SSC or firmness, or Ca content of leaves or fruit flesh at harvest or after 2 or 4 weeks in cold storage.

Irrigation

Trees supplied with optimum amounts of water (100% ET) during the season will produce maximum fruit size. However, higher SSC levels can be obtained by imposing moderate water stress during fruit growth prior to harvest. This will also reduce fruit size, but in some cases only slightly. When 'O'Henry' peach were held under moderate water stress (50% ET in the month prior to harvest), the stored fruit did not develop dry and mealy texture (internal breakdown symptoms). Moderate water stress can also reduce vegetative growth, thus maintaining lower fruiting wood, especially in high density plantings.

Over-irrigation (150% ET in the month prior to harvest) can be detrimental to long term productivity. Although fruit size may increase in the short term, the resulting excess vegetative growth can lead to shading out of lower fruiting wood and loss of yield. Saturated soil conditions can lead to tree decline.

In earlier work, extreme water stress resulted in small astringent fruit and unproductive trees. Imposing severe water stress in late summer (no irrigation during the growing season) on an early maturing cultivar decreased fruit quality the following year by increasing doubled and deep-sutured fruit.

Canopy position

During the last three seasons, we have evaluated fruit quality and postharvest performance of several peach, nectarine, and plum cultivars (Mitchell *et al.,* 1990; Saenz, 1991; Day *et al.,* 1992). Large differences in SSC, acidity, fruit size and storage potential were detected between fruit taken from the top, outside and inside canopy positions of open-vase trained trees. These differences in postharvest characteristics related to canopy position, became smaller when trees of early cultivars were trained to a V-shape, with the V oriented across the direction of the rows.

Thinning

Fruitlet thinning will increase fruit size while also reducing total yield, and thus a balance between yield and fruit size must be achieved. Generally, maximum profit does not occur at maximum marketable yield since larger fruit bring a higher market price. Leaving too many fruit on a tree not only reduces fruit size but also decreases their SSC. Thus fruit quality can be sacrificed in several ways by incorrect thinning. Grower experience is the best determinant of the optimum thinning level for each orchard and cultivar.

Pruning

The greater the light interception by an individual fruit and its surrounding leaves the better its quality (including fruit color, size, SSC, and flavor). Fruit in the top of the tree, for example, always have better quality than fruit in the lower, shaded part of the canopy. The differences can sometimes be substantial, even though the lower fruit remain on the tree for a longer period to reach maturity.

Prudent summer pruning practices which increase light penetration into the canopy will generally improve fruit quality. For example, the removal of interior water sprouts can significantly increase light penetration and improve fruit size, color and SSC of lower position fruit. However extensive summer pruning which removes many leaves surrounding the fruit can have the opposite effect, since these leaves supply carbohydrates to the fruit. In the same way, the practice of removing ("pulling") leaves around fruit to increase fruit color may decrease fruit size and SSC.

Postharvest factors affecting stone fruit quality

Harvest maturity

The maturity of stone fruits at harvest will determine their ability to achieve high eating quality, their susceptibility to mechanical injuries, their postharvest performance and their potential postharvest life. Any maturity index should clearly separate fruit based on physiological maturity, and any legal standard should be independent of growing conditions or location (Kader and Mitchell, 1989; Crisosto, 1992).

Fruit harvested at too high a maturity will be incapable of withstanding the rigors of postharvest handling and distribution, may have increased susceptibility to invasion by fruit rotting organisms. These fruits will have a short postharvest life, and may develop undesirable off-flavors and mealy texture.

Fruit harvested at too low a maturity will be incapable of ripening to their potential flavor and texture qualities. They will also lose water more readily, and may be at increased risk of physiological deterioration, especially if susceptible to internal breakdown.

With the increasing volume of fresh stone fruits entering long distance marketing, there has been a tendency to harvest the fruit at lower maturity; the idea being that they would be better able to carry to distant markets. The result has often been negative, however, because such fruit are more subject to shrivel and to the development of internal breakdown symptoms.

Handling injuries

Mechanical injuries can occur at any time from harvest through packing, handling and transportation (Mitchell and Kader, 1989a). Impact and compression bruises are normally the result of rough handling somewhere in the system. They typically follow abuses during picking, filling or transfer of field containers, packing line operations, transport and distribution. Recognizing that firmer fruit will withstand greater abuse, producers then tend to harvest at lower maturity.

Our studies have shown that careful monitoring and supervision throughout the system can reduce the injury potential. This includes training and supervision of pickers, field handlers, packing line workers, assemblers and loaders. Recently developed instrumentation can be useful in identifying potential injury locations on packing lines and other equipment.

In our studies (Mitchell *et al.,* 1991) the injury susceptibility of various nectarine, peach and plum cultivars increased at flesh firmnesses below about 3.5 kg-force. At similar firmnesses, plums were more resistant to bruising than were nectarines or peaches. Because of their greater susceptibility and their normal flesh firmness variability at harvest, nectarines and peaches that pass over typical packing lines in California should probably have an average flesh firmness of at least 4.5 to 5.5 kg-force. It would be desirable to improve the performance of these packing lines so harvest maturity could be advanced.

A limited US market has recently developed for higher maturity fruit. Called "Tree Ripe", such fruit are usually just harvested at a higher than normal maturity. Because they will not withstand the rigors of typical commercial packing lines, these softer fruit are packed on small, labor intensive hand packing lines. While the demand for such fruit is strong, the volume is limited by availability of suitable packing facilities and labor.

Vibration or abrasion bruising can result from fruit movement or rubbing during handling or transportation. This injury can cause discoloration of the fruit surface, accelerate water loss, and inflict fresh wounds for pathogen penetration. Incidence can be reduced by avoiding opportunities for fruit to abrade during handling, and by packing the fruit so they will be immobilized during transport.

Recent studies of surface discoloration, or "ink-staining", of peaches and nectarines (Crisosto *et al.,* 1992; 1993) have shown that discoloration can be the result of metal ion contamination of wound areas, especially by Fe, Al and Cu ions. Even foliar nutrient sprays and certain orchard fungicides can cause a problem if applied too close to harvest. Brushing and waxing of these fruits may increase susceptibility to the disorder.

Internal breakdown (chilling injury)

This disorder has not been reported on cherries, but occurs on many cultivars of all other stone fruits (Mitchell and Kader, 1989a). The injury results from prolonged exposure to temperatures below 10°C, and develops most quickly and severely in fruit held at 5°C. Most susceptible cultivars require 2 to 3 weeks exposure below 10°C for symptoms to occur, but a few peach cultivars will show problems after only one week of exposure. One or more visual symptoms can appear, including dry or mealy texture, failure to ripen, flesh browning, reddening or translucency, and dark discoloration of the stone cavity; and these symptoms are always accompanied by a loss of characteristic flavor of the fruit. Various conditioning treatments have been tried to delay development, but none are currently commercialized (Nanos and Mitchell, 1991a,b). While the disorder will develop in fruit held at or below 0°C, symptoms are less severe, and development is delayed. Thus, it is important that those cultivars be promptly cooled and held at temperatures of 0°C or below (depending on the freezing point of the fruit).

Temperature management effects on fruit quality

A summary of the effect of temperature on stone fruits is presented in Table 2. Temperature effects depend on the duration of exposure to a particular temperature and to the postharvest age of the fruit (Mitchell, 1987; 1989; Mitchell and Kader, 1989b). Stone fruits as a group are very responsive to high temperature exposure, such as delays between harvest and cooling. Problems can include high temperature injury, rapid softening, excess water loss and shrivel, and greater sensitivity to other disorders. Thus protection from heating after harvest and rapid movement to cooling are important. This is especially important with high maturity fruit, to avoid excessive flesh softening, but can also help to reduce the detrimental effects of internal breakdown.

Sweet cherries should ideally be cooled to near 0°C within 3-4 hours of harvest. Plums and normal maturity peaches and nectarines should be cooled to 5-10°C within 6-8 hours, and to 0°C within 24 hours of harvest; high maturity peaches and nectarines perform best if cooled to near 0°C within about 6-8 hours of harvest.

Stone fruits should be held between -0.5 and 0°C throughout the postharvest period, unless special conditioning treatments are being applied. Care should be taken to avoid prolonged exposure to intermediate temperatures because of the potential for flesh softening, shrivel, fruit rot development and internal breakdown (Mitchell *et al.,* 1989).

Table 2. Temperature effects on stone fruits (Modified from Mitchell and Kader, 1989a)

Temperature (°C)	Fruit response
>40	Skin scald and flesh breakdown
37 to 40	Failure to ripen
28 to 36	Abnormal ripening (mealiness, off- flavors)
15 to 27	Normal ripening (higher temperatures induce faster ripening)
0 to 10	Chilling injury/internal breakdown (severity depends on species and cultivar)
2 to 8	Most severe chilling injury
-0.5 to 1.5	Minimum flesh softening
-0.5 to 0	Best storage life
<-0.8	Possible freezing (depending on soluble solids concentration)

Fruit of cultivars that are susceptible to internal breakdown require a period of exposure, usually 2 weeks or more, to develop symptoms, and temporary holding near 5°C will not cause symptoms to develop. Thus prompt cooling and overnight holding at temperatures between 5 and 10°C to await next-day packing should pose no problem, provided the fruit are promptly cooled and held near 0°C following packing. If packing is to be delayed beyond the next day, then fruit awaiting packing should be cooled to near 0°C. Unfortunately, undesirable holding temperatures (around 4-6°C) that are often encountered inside loads of these fruits during transport to consumer markets can exaggerate deterioration.

Developing technology in fruit quality determination

Some of the newer research avenues have a potential to greatly improve our ability to measure and segregate fruit quality attributes in the postharvest handling system. Work with near-infrared light, magnetic resonance imaging, light transmittance, and methods for monitoring fruit impact-forces have shown promising results in non-destructively determining SSC, dry weight (and water content), flesh color, acid content, and flesh firmness. These may find uses both as inspection tools and for achieving large volume segregation at packing line speeds. As these technologies become commercially available, they can greatly improve the ability of stone fruit shippers to segregate fruit by their maturity, quality and handling ability.

The fruit quality system

The production and marketing of high quality stone fruits requires attention to all aspects of the system, from site and cultivar selection, through all cultural practices during fruit production, to harvest maturity, fruit selection and field handling, grading and packing, temperature management and distribution. Just as most cultivars of the past are unsuited to today's markets, so most of the older handling practices are not adequate to protect the fruit during long distance marketing. Perhaps this is most notable in temperature management, where newer methods of rapid cooling and low temperature holding are essential.

References

Crisosto, C.H. (1992). Stone fruit maturity indices: a descriptive review. In: *1992 Research Reports for California Peaches and nectarines*, Calif. Tree Fruit Agreement, Sacramento, CA, p. 10.

Crisosto, C.H. and Gardner, D. (1992). Evaluation of the effect of the brushing and waxing operation on peach and nectarine postharvest performance. In: *1992 Research Reports for California Peaches and Nectarines,* Calif. Tree Fruit Agreement, Sacramento, CA, p. 16.

Crisosto, C.H., Johnson, S., Cheng, G., Day, K., Gardner, D. and Crisosto, G. (1993). Skin discoloration on peach and nectarine fruit. In: *1993 Research Reports for California Peaches and Nectarines,* Calif. Tree Fruit Agreement, Sacramento, CA, p. 15.

Day, K.R., Johnson, R.S., DeJong, T.M. and Crisosto, C.H. (1992). Comparison of high density training systems and summer pruning techniques and timing. In: *1992 Research Reports for California Peaches and Nectarines,* Calif. Tree Fruit Agreement, Sacramento, CA, p. 4.

Kader, A.A. and Mitchell, F.G. (1989). Maturity and quality. In: *Peaches, Plums and Nectarines - Growing and Handling for Fresh Market,* Pub. 3331, LaRue, J.H. and Johnson, R.S. (eds). Univ. Calif. Div. Agric. and Natural Resources, Chap. 25, pp. 191-196.

LaRue, J.H. and Johnson, R.S. (eds) (1989). *Peaches, Plums and Nectarines - Growing and Handling for Fresh Market,* Pub. 3331, Univ. Calif. Div. Agric. and Natural Resources, Oakland, CA, p. 246.

Michailides, T.J., Ramirez, H.T., Morgan, D.P., Crisosto, C.H. and Johnson, S. (1992). Nitrogen fertilization affects fruit quality and susceptibility of nectarine fruits to brown rot. In: *1992 Research Reports for California Peaches and Nectarines,* Calif. Tree Fruit Agreement, Sacramento, CA, p. 24.

Mitchell, F.G. (1987). Influence of cooling and temperature maintenance on the quality of California grown stone fruit. *Rev. Int. Froid,* 10 (Mars): 77-81.

Mitchell, F.G. (1989). Cooling. In: *Peaches, Plums and Nectarines - Growing and Handling for Fresh Market,* Pub. 3331, LaRue, J.H. and Johnson, R.S. (eds). Univ. Calif. Div. Agric. and Natural Resources, Chap. 27, pp. 209-215.

Mitchell, F.G. and Kader, A.A. (1989a). Factors affecting deterioration rate. In: *Peaches, Plums and Nectarines - Growing and Handling for Fresh Market,* Pub. 3331, LaRue, J.H. and Johnson, R.S. (eds). Univ. Calif. Div. Agric. and Natural Resources, Chap. 23, pp. 165-178.

Mitchell, F.G. and Kader, A.A. (1989b). Storage. In: *Peaches, Plums and Nectarines - Growing and Handling for Fresh Market,* Pub. 3331, LaRue, J.H. and Johnson, R.S. (eds). Univ. Calif. Div. Agric. and Natural Resources, Chap. 28, pp. 216-222.

Mitchell, F.G., Mayer, G., Biasi, W., Gulli, D. and Faubion, D. (1989). Selecting and handling high quality stone fruit. In: *1989 Report on Research Projects for California Peaches, Plums and Nectarines.* Calif. Tree Fruit Agreement, Sacramento, CA, p. 15.

Mitchell, F.G., Mayer, G., Johnson, S. and Biasi, W. (1990). Factors in selecting and handling high quality stone fruit. In: *1990 Report on Research Projects for California Peaches, Plums and Nectarines.* Calif. Tree Fruit Agreement, Sacramento, CA, p. 27.

Mitchell, F.G., Mayer, G., Saenz, M., Slaughter, D., Johnson, S., Biasi, B. and Delwiche, M. (1991). Selecting and handling high quality stone fruit for fresh market. In: *1991 Report on Research Projects for California Peaches and Nectarines.* Calif. Tree Fruit Agreement, Sacramento, CA, p. 11.

Nanos, G.D. and Mitchell, F.G. (1991a). Carbon dioxide injury and flesh softening following high-temperature conditioning in peaches. *HortScience,* 26(5): 562-563.

Nanos, G.D. and Mitchell, F.G. (1991b). High temperature conditioning to delay internal breakdown development in peaches and nectarines. *HortScience,* 26(7): 882-885.

Saenz, M.V. (1991). Effect of position in the canopy on the postharvest performance and quality of stone fruit. In: *1991 Report on Research Projects for California Peaches and Nectarines.* Calif. Tree Fruit Agreement, Sacramento, CA, p. 19.

Source:

Calidad post-cosecha y productos derivados en frutos de hueso/Qualité post-récolte et produits derivés chez les fruits à noyau/Post-harvest quality and derived products in stone-fruits. Vendrell, M. and Audergon, J.M. (eds.). 1995.Proceedings of the CIHEAM/IRTA Seminar on "Calidad post-cosecha y productos derivados en frutos de hueso/Qualité post-récolte et produits derivés chez les fruits à noyau/Post-harvest quality and derived products in stone-fruits", Lleida, 17-18 October 1994. Ajuntament de Lleida, Lleida. 216pp.