INFLUENCE OF HARVESTING METHODS ON QUALITY OF DECIDUOUS TREE FRUITS

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Quality of deciduous tree fruits is determined by several factors, including appearance (size, shape, color, absence of decay and other defects), texture, flavor, and nutritive value. Harvesting methods, especially those involving a once-over procedure, may determine uniformity of maturity at harvest, which, in turn, influences these quality attributes. Maturity also affects susceptibility of the fruit to water loss and mechanical injury.

The harvesting system used and its management have a direct effect on incidence and severity of mechanical injuries on fruits; such injuries can result in tissue browning, accelerated water loss, and increased decay incidence. Mechanical injuries can also induce some undesirable compositional changes, such as loss of ascorbic acid content, and stimulate CO₂ and C₂H₄ production by fruits. Mitchell et al. (27) found that both impact and vibration injuries hastened deterioration, increased respiratory activity, and slightly increased C₂H₄ production of sweet cherries. An increase in C₂H₄ and CO₂ production by apples in response to bruising also has been reported (9, 23). We found (unpublished data) that impact bruising of clingstone peaches resulted in about 50% higher CO₂ and C₂H₄ production rates during the initial 12 to 24 hours of holding at 20°C; rates then returned to near those of control fruits.

Changes in the handling system necessitated by mechanizing harvest operations also can influence postharvest quality deterioration rates directly by affecting incidence and severity of mechanical damage and indirectly, by affecting speed of delivering fruits to a packinghouse or processing plant, and cooling and other temperature management procedures between harvest and preparation for market or processing. Generally, more damage can be tolerated with fruits used for processing than with those which are marketed fresh because processing is usually done within a relatively short period of time following harvest. Also, the severity of mechanical injuries may be reduced by processing, e.g., by peeling or trimming damaged surface areas and by reduction of discoloration intensity during heating.

The number and magnitude of impacts from drops on hard surfaces or on other fruits and vibration bruising while on horizontal conveyors or during transit are the main causes of damage to fruits which are mechanically harvested and handled. The magnitude of both quality and outright product losses are maturity-, time-, and temperature-dependent (29). As the fruit ripens and softens, it becomes much more susceptible to mechanical damage. Symptoms of mechanical injuries become more noticeable with time, especially at higher temperatures. Current technology limits shake-catch harvest to fruits for processing and fruits which can withstand some impact (10). Zahara and Johnson (38) estimated that 38% of the fruits for processing but less than 1% of fresh market fruits are harvested mechanically. The extent of harvest mechanization in the United States during 1979 was estimated to be 100, 85, 15, 13, 10, and 5% for prunes, sour cherries, sweet cherries, peaches, and apricots and apples, respectively (5). No mechanical harvesting of nectarines, plums, or pears was reported.

Claypool (7) and La Belle (18) reviewed the effects of mechanization on harvest quality and indicated that mechanical damage was the principal reason why most mechanically harvested fruits are considered unsuitable for the fresh market. Other limiting factors include excessive variation in maturity and the amount of unwanted plant parts (leaves, twigs, etc.) and defective fruits present in machine-harvested lots. The latter 2 problems require sorting of harvested fruits to eliminate defective ones and remove debris. Horsfield et al. (13) found that removing culled at the harvester rather than at a central sorter or at the cannery was better because it was least costly and caused the fewest bruises. Uniformity of maturity at harvest is influenced by cultivar, cultural practices, use of growth regulators, and climatic conditions. Fruit maturity has an important effect on the force required for removal, on mechanical properties, and on relative susceptibility of the fruit to mechanical damage. Until cultivars with uniform fruit maturity are developed, selective harvest will be needed. Lack of uniformity in maturity among fruits in once-over harvesting operations was identified as the most important factor influencing fruit quality (29).

Fruit injury in mechanical harvesting can occur during detachment from the tree (due to impacts with leaves, twigs, and other fruits while being shaken), while falling through the tree, and during catching and collecting operations. Mechanical injuries result from improperly padded surfaces, poor protection from fruits falling on each other, poor conveyor design and operation, and container-filling devices that permit a free fall of fruit for a distance sufficient
to cause bruising. Many improvements that minimize these problems have been made in design and operation of harvesting machines during the past 15 years. Fillers for bins and gondola trucks which reduce damage have been developed (30). Changes in the production system to make the tree more adaptable to mechanical harvesting also have been evaluated. These include shape and size control methods for trees (genetic and cultural), which can help in reducing impact injuries.

A brief review of research efforts since 1969 on harvest mechanization of deciduous tree fruits and its impact on quality follows.

Apple
Shake and catch systems generally have not been satisfactory for fresh-market apples because of their high susceptibility to bruising; use of these systems for processing apples has been limited (24). Tennes et al. (33) reported 11% to 40% bruised fruits in mechanically harvested apples, compared with 0% to 18% for hand-picking. Larsen (20) concluded that mass-removal systems for fresh-market fruits probably will be restricted to small trees so that a fruit will fall only a short distance and not strike any branches or other fruits during its descent. However, mechanically harvested apples were acceptable for processing (19). Losses in the stored fruits were closely related to the number of skin breaks at harvest, and were greater in the soft cultivars 'McIntosh' and 'Cortland' than in the harder cultivars. Small fruits had the lowest losses within each cultivar. Cain (6) concluded that use of smaller trees is the most economical method for bruise damage reduction during mechanical harvesting. In a study with small 'Red Delicious' apple trees treated with damaenzide and harvested with the low-profile catching frame and trunk shaker, fruits were 86% extra-fancy, 5% fancy, and 11% cull (2). Untreated 'Golden Delicious' harvested from medium-size trees averaged 37% cull fruit. Berlage (2) also reported that delays at ambient temperatures between harvest and processing can result in increased attack by various pathogens, including Penicillium expansum, which is capable of producing the mycotoxin patulin. Fridey et al. (12) demonstrated a potential for mechanical harvesting of 'Golden Delicious' and 'Red Delicious' apples with acceptable fruit quality using a collector-decelerator system. However, mechanical harvesting still seems highly unlikely for fresh-market apples, but its use for processing apples will continue to increase.

Pear
Flesh bruising during harvest and handling operations before the pears are ripe result in brown tissue which downgrades their quality as fresh or canned fruits. Variable maturity is another limiting factor for mechanical harvesting. Mehlischau et al. (26) reported that 'Bartlett' pears harvested by use of a collector-decelerator system yielded about 90% choice halves compared to 61% for fruits caught on a conventional catch frame. Trelissed pear trees may be suitable for mechanical harvesting if fruits are used for processing (36).

Apricot
Lack of uniform maturity, both within individual trees and between trees, resulted in the harvested fruits containing too many immature or overmature apricots in once-over mechanical harvesting operations. Fruit damage during mechanical harvesting, using impact instead of inertia shakers for fruit removal and well-padded catching frames, was only 3% higher than during hand-harvesting (14). Harvesting individual trees mechanically when 80% of the fruits on a tree are at optimum ripeness, preceded by hand-harvest to remove the ripper tip fruits, may have potential (14). This method will also require sorting out less mature fruits for ripening before canning. Ethylene treatment can be used to attain faster and more uniform ripening of these fruits (4). Hand-harvest will most likely remain the method of choice for fresh-market apricots, because of excessive fruit injury, increased susceptibility to decay, and the greater need for selecting fruits at optimum maturity when mechanical harvest is used.

Peach
Limitations to mechanical harvesting include bruising, variation in fruit maturity, low tree profiles which make use of portable catch frames difficult; and damage to tree trunk and limbs from shaker action. However, with proper management of the harvesting operation, clingstone peaches can be successfully harvested mechanically (11, 13, 29, 39). In 1981, about 35% of the clingstone peach crop in California was harvested mechanically. Since bruising can be higher in mechanically harvested fruits, they should be processed soon after harvest in order to minimize flesh browning. There are large differences in fruit browning potential among cultivars, differences that are related to their content of total polyphenols and polyphenol oxidase activity (15). Thus, some cultivars are more adaptable to mechanical harvesting than others. Freestone peach cultivars generally are more susceptible to bruising and browning than clingstone cultivars. Preharvest application of damaenzide advanced fruit maturity but did not influence postharvest ripening rate (28, 35). Trellised peach trees were found more suitable for mechanical harvesting because of reduced fruit bruising (36). Bruising due to impacts, which may be manifested internally in the flesh, is a major limiting factor for harvest mechanization in fresh-market peaches (17). However, encouraging results on mechanical harvesting of peaches for fresh market have been reported (31, 32). Sims et al. (32) described an integrated system of growing, harvesting, and handling peaches using growth regulators, a mechanical harvester, and a portable field dumper-sorter capable of applying fungicides, which would make it possible to deliver acceptable quality fresh-market peaches. They identified cuts which led to fruit rot development during storage as the most serious problem related to mechanical harvesting.

Plum
Using an in-tree collector-decelerator catch frame for harvesting plums, Mehlischau et al. (25) found small differences in quality between hand- and machine-harvested 'Queen Ann' fruits. However, the percentage of marketable fruits was much lower in machine-harvested (74%) than in hand-harvested (93.7%) 'Laroda' plums. Additional improvements in the machines and the production system are needed before mechanical harvesting can be used for fresh-market plums.

Sour cherry
Scald is the major grade-lowering defect resulting from mechanical harvesting of sour cherries for processing (1, 3, 20). Cellular disruption due to impact bruising during mechanical harvesting facilitates the movement of tannins from epidermal cells into the outer cortical cells and thus leads to the development of scald (1). Unless cooled quickly to 15°C or below, a bruised cherry will scald (20). Red sour cherries have been mechanically harvested successfully, provided they are cooled to below 15°C within 30 min after harvest (21, 37). Looney and McMechan (22) found the use of preharvest damaenzide and ethephon treatments to be effective in facilitating mechanical harvesting of sour cherries.

Sweet cherry
Mechanical harvesting of fresh-market sweet cherries currently is not feasible because of bruising, pitting, and stem detachment from the fruits (8). Use of ethephon to facilitate mechanical harvesting reduced pitting and torn stem attachments, but did not reduce bruising (8). Processing sweet cherries have been harvested mechanically with minimal losses when they were immediately placed in brining solutions (16, 20, 34).

Concluding remarks
1. Management of the harvesting operation, whether manual or mechanical, can have a major impact on quality of the harvested fruits. Proper management procedures include selection of optimum time to harvest in relation to fruit maturity and climatic conditions, training and supervision of workers, and effective quality control.
2. Expedited and careful handling, immediate cooling after harvest, maintaining optimum temperatures during transit and storage, and other effective decay-control procedures are important factors in the successful postharvest handling of fruits regardless of their
harvest method, but are more critical in the case of mechanically harvested fruits.

3. Despite all the previous efforts by researchers and machine manufacturers to develop mechanical-harvesting equipment for deciduous tree fruits, most still are hand-harvested. Tree nuts, prunes for dehydration, and sour cherries for processing are the exceptions.

4. The continuing consumer demands for high flavor-quality fresh fruits indicate the need for picking fully ripe fruits, which cannot be mechanically harvested without serious damage. These demands are illustrated by the continuing expansion of direct marketing outlets (farmer’s markets, roadside stands, “pick-your-own” operations, etc.). It is likely that hand-harvesting will remain the method of choice for most fresh-market fruits in the foreseeable future.

5. The success of future research efforts in developing mechanical-harvesting systems will require continued cooperation between horticulturists and agricultural engineers. Research by horticulturists should emphasize modifications in the production systems of deciduous tree fruits, such as: a) reducing tree size by use of dwarfing rootstocks or genetically dwarfed cultivars; b) modification of tree shape to ensure fruit removal with minimum within-tree impacts; c) selection of cultivars whose fruits are less susceptible to bruising and browning; d) attainment of more uniformity in fruit maturity via selection of new cultivars, application of growth regulators, and other treatments; and e) use of abscission-promoting growth regulators to improve fruit removal efficiency. Research by agricultural engineers should continue to improve fruit detachment and collection systems to minimize mechanical injuries to fruits and trees.

6. In addition to overcoming the technological limitations, future developments in mechanical harvesting will depend on economic considerations, i.e., cost/benefit ratio of mechanical vs. hand-harvesting of a given commodity in a specific production area. Also, concern about the social impact of mechanization will continue to influence the amount of resources allocated to harvest mechanization research in public institutions.

Literature Cited


