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**INFLUENCE OF MECHANICAL HARVESTING ON QUALITY OF NONFRUIT VEGETABLES**

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Quality in this discussion is interpreted as the market quality, and not nutritional quality, of products. Market quality is comprised of the inherent quality and maturity of a product at harvest, and the condition of the product after the harvesting operation. Mechanical harvesting (MH) includes handling steps from removing plants or plant parts from the field (soil or plant) to delivering them onto a field packing facility or field vehicles for subsequent transporting to packing houses or processing plants.

MH is employed when the overall cost of doing so is less than for manual harvesting of a product. MH is used successfully for many vegetables for processing and fresh market (4). MH may increase or decrease the variability in product maturity, the amount of mechanical damage (bruises, cuts, punctures, abrasions, and skinning) sustained by products, and the amount of subsequent decay of products. The magnitude of these disorders developed depends largely upon the plant and soil conditions at harvest time, the time of day of harvest, product maturity, and the skill of the harvester operator and related workers. When the amounts of any or all of these disorders increase, mechanical harvesting requires more product grading to be successful.

Effects of MH on the quality of vegetables differ with types of vegetables, plant parts harvested, and among cultivars. A brief review of these effects follows.

**Aboveground vegetables**

*Asparagus.* Nonselective MH causes harvesting of spears too short for traditional marketing, damages tips below the soil surface, and causes too much soil to be mixed with the product. These effects cause reduced yields (4). Some short spears are harvested even by hand-harvesting and, in many operations, are culled. However, one California shipper has developed a profitable market for bulk-packed asparagus tips and short spears.

*Brussels sprouts.* Leaf damage caused by MH is not a major concern with the processing crop (95% of the U.S. production), but detracts from the appearance of the fresh-market product (4).

*Cabbage.* The processing crop is mechanically harvested in most areas. The amount of leaf damage occurring on the processing crop would be unacceptable on fresh-market cabbage. However, with proper harvesting and handling, cabbage could be mechanically harvested successfully for fresh market (11).

*Caiflower.* The growth rate of unharvested heads was significantly lower after MH than after hand-harvesting. MH caused more broken leaves than hand-harvesting when plants were very succulent. This could result in increased curd yellowing on the remaining heads. Very slight head damage was observed after jacket leaves had been removed, and damage was not significantly different between hand- and mechanically harvested heads. MH would be more adaptable if the number of harvests was reduced from the number used for hand-harvesting (8).

*Celery.* Although MH is used commercially to harvest some of the crop in both Florida and California, there is very limited published information on the effects of the practice on the subsequent quality of the celery. In both states, MH is used by some shippers to harvest stalks that are trimmed to be packed as celery hearts. Thus, any damaged outer petioles are removed in the trimming operation. In California, celery destined for soup canners is mechanically harvested. When undercutting is too high, stalks will not remain intact and can be used only for processing. Developing a market for the resulting detached petioles has not been successful commercially.

*Leafy greens.* These include collards, endive, escarole, kale, mustard, spinach, and turnip greens. Proper height adjustment of the lifting-belt is necessary to prevent bunching yellowed or dirty lower leaves, or attached weeds, which detract from the market quality of greens. Time of day of harvest affected bunch crispiness.
with morning-harvested bunches being more crisp than those harvested in the afternoon. Bunches tied with flat strings had less stem and leaf cutting than those tied with round strings (10).

Crisphead lettuce. Head maturity (firmness) is the most important criterion in harvesting judgment. Heads selected must be of desired maturity (fairly firm to hard). Some markets prefer firm-to-hard heads, while other markets (e.g., overseas military bases and export markets) prefer fairly firm to firm heads. In California, mechanical harvesters equipped with gamma-ray or X-ray sensors for density provided the least median number of errors (6% and 5%, respectively), compared to an 18% median error for a 25-man, hand-harvesting crew (2). It was easy to adjust the gamma-ray or X-ray sensors to meet changing market demand for lettuce maturity (density).

Moderate and severe mechanical damage to heads in field-packing and box-closing steps was measured at 33% by Hinsch (7) in California. In mechanically harvested, jumble-filled, large bins, there was more crushing and bruising of lettuce than in hand-harvested lettuce packed in cartons. The concept of MH and field-packing subunits (several heads connected in a flexible tube within a large, master container) would reduce the number of handling steps between harvesting and retailing from 27 to 9. This presumably would reduce mechanical damage to heads (6). A "tubes and cubes" lettuce handling system reduced the number of times that lettuce would be manually handled, provided greater protection against crushing and handling damage, and allowed for better circulation of cold air through the container during transit and cold storage (6, 7).

Rhubarb. A small part of the rhubarb production destined for processing is mechanically harvested. Some stalk damage, which reduces market quality, has been reported. One harvester operator reportedly economically sorted out damage-free stalks for packaging and sale on the fresh market (9).

Below-ground vegetables

These include roots, bulbs and cloves, and tubers.

Roots. MH is used for harvesting both processing and fresh-market root vegetables without tops (table beets, carrots, horseradish, parsnips, radishes, rutabagas, and turnips). Although noticeable mechanical damage occurs in harvesting, it generally is not considered important unless it becomes excessive, because the products destined for processing are considered to be "hardware items". Products destined for fresh market are rapidly and thoroughly cooled to temperatures which greatly inhibit manifestation of the damage on the roots. Precision planting and proper adjustment of the topping mechanisms are important to minimize root damage from bruising and cutting (4). This is a good example of the consuming public being educated to accept a higher level of damage on products and to accept a product form (topless) that facilitates MH.

Sweet potatoes. Sweet potatoes for processing are harvested both by mechanical and hand-harvesting. MH generally is not used for roots destined for fresh markets. Roots of 'Jewell' were less damaged, and experienced less weight loss, than 'Centennial' roots in both hand- and mechanical-harvesting operations (1). MH caused a noticeable amount of skinning of roots; however, better curing and storage conditions and practices would reduce weight loss during storage. Slight darkening of the skin was noted on MH 'Jewell' roots. This darkening was attributed to enzymatic browning of multiple small, sand abrasions. 'Jewell' roots, mechanically harvested into a bulk hopper, sustained less damage and less reduction in packout than when harvested into pallet bins, and about the same amount of damage and packout reduction as roots commercially harvested by conventional means.

Bulbs. Both garlic and dry onions are mechanically harvested for processing, as is some of the fresh-market onion crop. In harvesting fresh-market onions, the bulbs are loosened in the soil by mechanical undercutting. Subsequent harvesting operations may be performed mechanically or manually, depending primarily upon how tender the bulbs are. The more tender cultivars are easily damaged by bruising during harvesting, topping, and handling and are very susceptible to decay during storage (4). Onion cultivars with thicker necks and softer bulbs are more easily damaged than those with narrower necks and harder bulbs. Rapid and thorough curing after harvesting helps to inhibit development of decay on bulbs. Consumers are less particular about the length of tops of garlic than of onions. Present inability to automatically trim tops and roots of mechanically harvested onions to lengths comparable to those on hand-trimmed bulbs has delayed market acceptance of MH for onions.

Tubers. Potatoes are mechanically harvested for both processing and fresh market. Extensive research and extension studies have been conducted on various aspects of MH with potatoes. Considerable emphasis has been placed upon the effects of MH on subsequent tuber quality. There is probably more published information on the effect of MH on potato quality than on any other nonfruit vegetable crops. Smith (12) provides an excellent coverage of the subject in his book. Efficient vine-killing reduces the amount of skinning and bruising during harvesting and storing of potatoes. Rapid vine-killing generally results in less tuber injury during harvest. Increased time between vine-killing and harvesting decreases tuber susceptibility to bruising and skinning. However, early killing of vines reduces yields and reduces specific gravity of tubers, compared with tubers from vines killed later. Greatest reduction in specific gravity occurs when vines are killed rapidly. Internal discoloration (primarily confined to the xylem) of tubers has been observed following killing of vines, mostly in drier areas of fields. Early vine-killing causes the most discoloration.

Types of harvesting injuries that reduce market quality and pack-out yield include cuts, cracks, bruises, and skinning. Commonly, 10% or more of a crop is damaged during harvesting. Careful operation of harvesting and handling equipment can reduce damage to 5% or less. Tavemetti and Baghott (13) found practically no difference in mechanical damage between 2-row digging and hand-picking compared with MH by the time the tubers reached storage. Smith (12) suggests the following steps to reduce tuber damage in MH:

1) Keep digging points deep enough to be below the bed or earth surrounding the potatoes. This causes the tubers to be transferred to the chain on a cushion of soil, reducing tuber-cutting and other injury.
2) 7) Maintain chain speed at about 8 revolutions per minute (38.1 to 45.7 m/min.) Excessive digger-chain speed is the single most important cause of tuber injury.
3) Maintain chain agitation to minimum amount necessary. Increase agitation only when needed to adapt to certain soil and digging conditions.
4) Keep digger chain tight enough to prevent sagging or whipping.
5) Shield sharp ends of chain links, pad deflectors, and sharp points with rubber or belting.
6) Reduce tuber drops to 15 cm or less.

Potato damage also occurs and must be kept minimized in the transferring of tubers from harvesters to field hauling equipment. This can be aided by adjusting the loader so that tubers do not fall more than 10 to 15 cm, and by coordinating harvester and truck speeds so that the tubers are properly delivered to the truck with minimal damage. Unloading potatoes from trucks into water flumes at packing houses also reduces injury.

Conclusions

Successful adaptation of MH requires skillful harvester operation. It may require different methods, or modifications of present methods, of handling products from fields to retail stores (e.g., faster and better curing of Irish potatoes, sweet potatoes, and dry onions, or prompt and thorough cooling of certain root, stem, and leafy vegetables). It also may require developing markets for products or product forms not traditionally marketed (e.g., asparagus tips, cauliflower florets, broccoli stems, and celery petioles) in commercial marketing outlets. Education programs may be needed within the fresh produce marketing and distribution industry, and with consumers, on the value of products as presented after mechanical harvesting (e.g., root vegetables without tops). Horticulturists have the capability and opportunity of assisting in developing and adapting faster and wider acceptance of mechanical harvesting for vegetables.
Literature Cited


