Engineering Problems in Harvesting Citrus Fruits

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PRODUCTION figures (1)* for the 1959-60 season show that Florida produced 30,000 more tons of citrus fruit than the total United States production of apples, peaches and pears.

In 1960-61, Florida produced about 93 million boxes of oranges, 32 million boxes of grapefruit and 3½ million boxes of tangerines. (A Florida field box is about 2¼ U.S. bushels.) Twenty-nine percent of this fruit was consumed fresh, 50 percent was processed into frozen concentrate, and the remaining 21 percent went to other canned products.

Most deciduous fruits have a critical harvest period of from a few days to two weeks of optimum maturity in which the fruit must be picked for storage or direct utilization. In the case of citrus, however, the best place to store it is on the tree and any particular variety can be left on the tree several months after reaching maturity and still maintain an acceptable quality. This characteristic allows considerable freedom in the harvest schedule. Close to 60 percent of the oranges harvested in Florida are early and mid-season and the remaining 40 percent are late-season oranges (Valencia). The total harvest season extends from late September to early June or about nine months of the year.

A five season (1956-61) average on tree return for oranges was about $2.30 per box. Of this, about 35¢ per box went for picking which is defined as the operation of getting the fruit off the tree and into a highway truck. This picking cost includes labor, equipment, maintenance and depreciation as allocated by Spurlock (2).

The basic picking system that has been in use for years uses the 90-lb field box as the picking and hauling container. The picker using a ladder picks into a picking bag that holds 75 to 90 lb of fruit. He works from the top of the tree down the ladder and empties the bag into the box. The citrus fruit picker averages about 60 boxes of oranges a day on a piece work rate of 17 cents per box, or $10.20 per day. A driver and loaders using a "goat" (stripped down truck chassis) pick up the filled boxes and move them out of the grove to a highway vehicle. The operations from the field container to the road vehicle have been developed into a wide variety of systems depending on the volume and utilization of the fruit (7). It is estimated that only about 7 percent of the individual citrus-grove owners actually organize and supervise their own harvest operation. Most citrus groves are either company owned, members of cooperatives, or contract harvested by regular licensed citrus dealers. Harvesting equipment must therefore be quite mobile and versatile since it will be used in a large number of widely scattered groves of all ages, types and varieties of citrus.

Table 1 lists a number of handling methods, equipment and labor involved along with a few of their advantages and disadvantages. The handling methods in Table 1 do not show the trucks needed to haul the fruit and farm tractors or busses to haul the picking crew from packinghouse to grove or between groves. Most packinghouses and custom harvesters must maintain a sizeable maintenance shop to keep all of the field equipment in repair. Usually, however, when the field box is eliminated, there is a subsequent reduction in associated harvest costs of 5 to 8 cents per box.

Three different harvesting methods (3) have been pursued in trying to improve on the bag-and-ladder method of picking. These experimental harvesting and handling systems are the result of research work conducted by private individuals and industry, the Florida Citrus Commission, the Florida Experiment Station, and recently the U.S. Department of Agriculture.

One approach has been the development of picking aids to eliminate the bag and ladder and increase the time spent picking fruit. Mobile ladders, (4) picking tubes, self-propelled individual platforms, team platforms, and pick-and-drop catch frames have been tried to improve picking efficiency. The maximum increase in productivity per picker has been about 40 percent and has not been justified economically because of machine costs and the need for extra labor such as tractor driver or machine operator. One hundred percent fruit removal is possible with these methods. The economics of mechanized picking aids look more promising as picking costs rise.

The second area of harvest development has been in semiautomatic or batch-type picking machines which eliminate the picker entirely and rely on some principle such as rolling, twisting, or shaking the fruit off the tree. Machines in this category must make contact with the fruit or tree to remove the fruit in multiples. Considerable work has been done on the development of spindle-type picking machines which project a bank of rotating flails, spindles, or augers into the tree and knock or "screw" the fruit off the tree. None of these machines have proved entirely successful because of insufficient increases in productivity, excessive tree damage, and high machine costs.

Probably the most promising equipment in this area of semi-automatic machines is the shake-and-catch method (5) employing a tree shaker and a mobile catching frame similar to that used on some deciduous fruit and nut crops. Cable shakers; boom-type, fixed-stroke shakers, impact knockers, and inertia-type tree shakers have been

TABLE 1. CITRUS FRUIT HANDLING METHODS IN PRESENT USE FOR FRESH AND PROCESSING OUTLETS

Method	Advantages	Disadvantages
1 Hand-dump field box (7) (1 foreman, 4 loaders)	(a) Very flexible system (b) Little mech. equipment	(a) Hard physical labor (b) High handling cost per box (6-7¢)
2 Field box-bulk "goat" (7) (1 foreman, 2 loaders, 2 drivers)	(a) Handle high volume of fruit (b) Can have rel. long dist. to loading area	(a) Hard Physical labor (b) More equip. needed
3 Field elevator-bulk "goat" (7) (1 foreman, 3 drivers)	(a) Eliminate field box (b) Less loading labor	(a) Pickers must pool fruit (b) Loading area elev. also needed (c) Crew size limited
4 Field trailer-tractor (7) (1 foreman-driver, 1 driver)	(a) Eliminate field box (b) Less labor, less cost (2½ to 4¢ per box)	(a) Difficult to trans. trailers, tractors from grove to grove (b) Roadside elev., large loading area needed
5 Basket (or pallet box (7) tractor lift) (2 foreman-drivers)	(a) Eliminate field box (b) Less labor, less cost (2 to 4¢ per box)	(a) Tractor less maneuverable with front-end loader (b) Labor must be more skilled
6 Basket-loader boom-hi-lift "goat" (1 foreman, 1 driver)	(a) Eliminate field box (b) Less labor, low cost (c) System very mobile	(a) Skilled operators (b) High equip. and maint. cost
7 "Chapman" loader (2 foreman-drivers)	(a) Excellent for small blocks, spot-pick, close to plant (b) Eliminates field box (c) No-loading area necessary (d) Very mobile system	(a) Pickers must pool fruit (b) Crew limited, must pick close to truck (c) Not good over few miles from receiving line

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tried under a variety of grove conditions. To date, the inertia shaker has shown the most promise. The inertia-type tree shaker is usually a hydraulically powered unbalanced mass oscillating on one end of a boom of which the other end is attached to a tree. A shaker amplitude of six inches at frequencies of 600 to 800 cpm have given the best results. The amplitude imparted to the tree, however, is only about 2½ in., depending on the size of wood at the attachment. Fruit removal with this type equipment varies from 65 to 90 percent depending on the fruit maturity, tree size and shape. Frequency, stroke, duration of stroke, and angle of attachment to the limb are machine factors which also affect fruit removal. A three or four man crew is needed with this type of equipment. No production trials have been conducted to determine work rates because the percent fruit removal is still too low to be economical under present conditions.

Work is being done on tree pruning to adapt a tree for mechanical shaking and with chemical looseners in an effort to increase the percent fruit removal by induced abscission. Bark damage has been a problem, under some conditions, and this is also being investigated. Tree injury could be a limiting factor in the use of tree shakers because of the abundance of fungus organisms in a subtropical climate. The tree shaker will work under most grove conditions with only minor changes in tree shape.

The Valencia variety of oranges usually has the next season's crop developing on the tree at the time that this season's crop is being picked. This resulted in a loss of some of the future crop when the tree shaker was employed. Since about 40 percent of the oranges are of the Valencia variety, this is a serious problem.

The third area of development in citrus-harvest mechanization has been toward fully automatic equipment that requires a minimum of supervision by the operator and does not make physical contact with the fruit or tree.

A blast of high-velocity, high-volume oscillating air has shown considerable promise in the development of a continuous-type harvesting machine (6). Tests with an oscillating, air-blast machine at air velocities of 8,600 to 10,000 fpm traveling at ¼ mph removed from 40 to 95 percent of the citrus fruit. The percent removal was greatest at high air velocities in larger sized fruit having a high Brix/acid ratio and an oscillating rate of approximately 60 cpm.

This method of harvest is not satisfactory for fresh fruit in its present state and leaf damage appears to be a problem. Tests with the spray application of polyvinyl solutions to the trees prior to harvest tended to reduce the leaf damage. Removal of next year's crop in Valencia oranges may be a limiting factor with that variety.

The three areas of picking-machine development discussed here show considerable promise, but all have definite and major disadvantages that must be overcome. The results presented were primarily concerned with oranges since they compromise the major portion of the Florida citrus industry.

In summary, considerable progress has been made on the development of equipment and methods for harvesting and handling of citrus fruits. Most harvest equipment is limited by low fruit removal and high equipment cost. Should the economics of the citrus industry change due to further reductions in picking labor or increased production (180 million boxes predicted by 1969-70), some of these machines may be entirely feasible. Though fruit picking has not changed in the last fifty years, field-handling methods have improved greatly and enabled the industry to reduce costs and labor needed in the field. The engineering problems of citrus harvesting become much more complex when you consider spot picking, fruit clipping, and handling the more tender fruits such as tangerines.

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