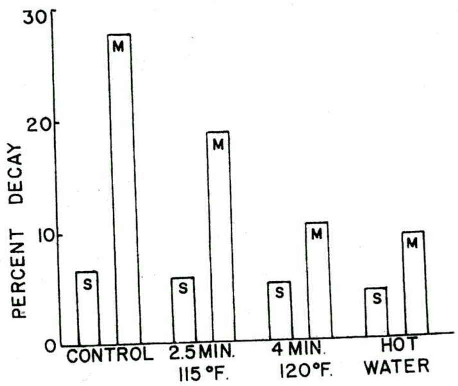

Figure 3. Effects of color-adding and hot water treatments on decay of Temple oranges by stem-end rot and mold at 17 days from packing.

similar reduction of decay by the hot water treatment indicated that a temperature effect was responsible rather than fungicidal action by any chemical in the emulsion.

Figure 3 shows the average decay due to stem-end rot and mold at 17 days from packing for control samples without color-add, for samples color-added for 2½ minutes at 115° F. and for 4 minutes at 120° F. The results of treatment with hot water for 4 minutes at 120° F. are also shown. No significant differences in stem-end rot are shown by the various treatments. Decay due to mold was appreciably reduced by color-adding for 2½ minutes at 115° F., the legal limits for Temple oranges and tangelos. Further reduction in decay by mold was shown for samples color-added at the legal limits for oranges of 4 minutes at 120° F. Hot water treatment for 4 minutes at 120° F. gave similar results. Reduction of decay by mold thus accounts for the improved keeping quality shown by color-added Temple oranges.

Summary

1. The color of Temple oranges is improved by color-adding but does not exceed that of natural-color fruit selected for best color.
2. Residues of Citrus Red No. 2 increase with time of exposure to the color-add emulsion but are well within the legal tolerance of 2 ppm.
3. Exposure of Temple oranges to the elevated temperature of the color-add emulsion results in appreciable reduction in decay due to mold.

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HARVESTING CITRUS FRUIT WITH AN INERTIA SHAKER

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For many years the concept of shaking trees to remove their fruit has been practiced in the commercial harvesting of nut crops such as walnuts, pecans, etc. Recently this concept has been adapted to commercial harvesting of prunes (6) and red tart cherries (5). At present, it is also being tried experimentally in peaches harvested for processing (3).

The commercial machines available may be classified as fixed stroke and inertia shakers, depending on the principle at work in releasing fruit from a tree. Usually a catching frame is employed in combination with the shaker to collect the fruit as it drops from the tree.

The authors (4) evaluated a fixed stroke shaker in 1958, and found it unsuited for citrus because of low fruit removal and poor maneuverability. Coppock (2) discussed the concept of a tree shaker and catch frame for fruit harvesting using an inertia shaker. The objective of the experiments reported in this paper was to provide additional information on the merits of this concept for harvesting citrus. Emphasis was placed primarily on fruit removal without much regard to the catching and collecting of fruit.

Experimental Equipment

The inertia shaker shown in Figure 1 was used in the tests. It employs the same inertia principle developed by Adrian and Fridley (1)

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[1]Cooperative research by the Florida Citrus Commission and the Citrus Experiment Station.

Figure 1.—Inertia tree shaker used to harvest citrus. A rotating eccentric weight of 85 pounds produces the shaking action.

for harvesting prunes. It consists of an eccentric drive with an unbalanced weight of 85 pounds attached to a claw by a 12-foot steel tube. The unbalanced weight, made up of the hydraulic drive mechanism, oscillates through a fixed stroke of four inches at frequencies ranging from 0 to 1,000 cpm. The moving parts are suspended on a turret mechanism. In operation the shaker was manipulated into the tree and attached to a primary limb. Vibration was isolated from the transport unit by a flexible mounting. Power was supplied to the shaker by an 11 hp hydraulic motor.

Test Procedure

The procedure for obtaining fruit removal and fruit size data was as follows:

1. Clear area under tree of fallen fruit and trash.
2. Shake tree with the shaker adjusted for optimum performance under the particular grove conditions.
3. Collect fruit that falls to the ground and determine the total number and average size, using a standard sizing machine.
4. Pick fruit remaining on the tree after shaking and determine total number and average size, using a standard sizing machine.
5. Calculate the per cent fruit removal based on the total number of fruit on tree.
6. Determine Brix/acid ratio (7) of both fruit shaken off and for that which remains on the tree.

The separation force required for separating a fruit from its stem was determined by taking a random sample of specified number of fruit from each tree. Each fruit was removed with a 4-inch stem attached. The fruit was clamped in a stationary position and a force was applied to the stem, which was held at a specified angle in relation to the major axis of the fruit. The force was measured by means of a spring scale attached in the force system.

The per cent decay was obtained from samples of 100 fruit, each held in a 60° F. room. A count of decayed fruit was made weekly for three weeks.

Field Tests

Valencia Oranges, 1961.—Twenty-year-old Valencia orange trees averaging 18-20 feet in height were shaken at two-week intervals beginning on April 26, 1961. This date corresponds to the date of fruit maturity as measured by the standard fruit maturity test (Brix/acid ratio). The test area was divided into four 5-tree plots. The first plot was shaken April 26 and a new plot plus the previously shaken plots were shaken at two-week intervals until June 5. Fruit removal data, determined for each time the trees were shaken, are presented in Table 1.

Hamlin Oranges, 1961.—The inertia tree shaker was tested in a 25-year-old grove of Hamlin orange trees ranging in height from 18 to 24 feet. Five-tree plots were harvested at various intervals between September 12 and December 20. Figure 2 shows the per cent fruit removal and Brix/acid ratio for this test plotted against time from minimum maturity standard.

Pineapple Oranges, 1962.—The same type experiment used on Hamlin oranges was conducted on Pineapple orange trees spaced 25 x 25 feet with tree height averaging 20 feet. Plots of three trees each were harvested on January 8 and 29, and February 19, 1962. Figure 3 shows the per cent fruit removal plotted against Brix/acid ratio.

Grapefruit, 1962.—Three Marsh seedless grapefruit trees were shaken on February 26, and

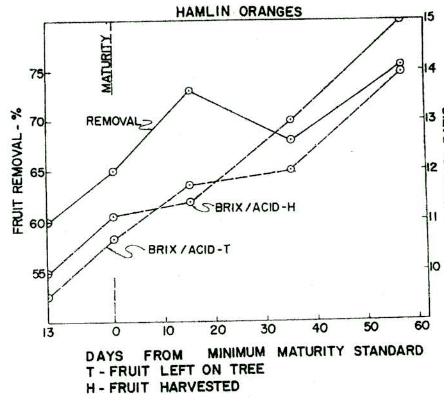

Figure 2. Relation between fruit removal, Brix/acid ratio and time from minimum maturity standard.

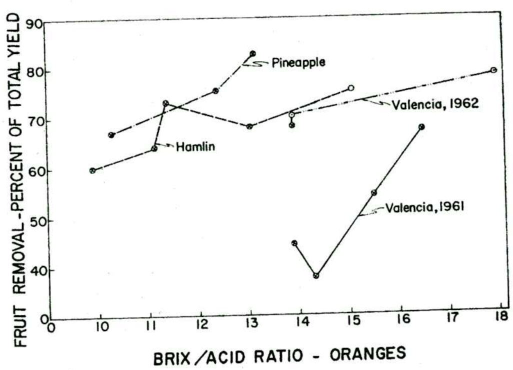

Figure 3. Effect of Brix/acid ratio on fruit removal when harvested with inertia tree shaker.

Table 1. Per cent fruit removal obtained by inertia shaker in Valencia oranges.

Plot No.	Harvest Dates--1961[1/]				Total Removal Per Cent
	April 26	May 8	May 23	June 5	
1	44.24	16.47	10.66	12.83	84.20
2	--	37.53	18.68	18.96	75.17
3	--	--	54.92	26.24	81.16
4	--	--	--	67.60	67.60

1/ Average of five trees.

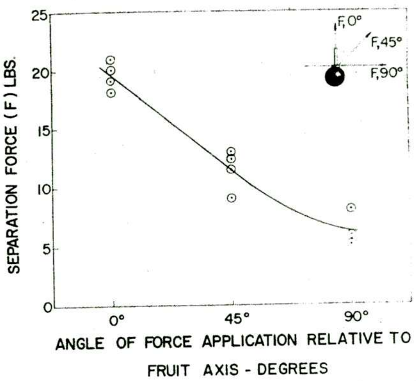

Figure 4. Relationship between separation force and the angle of pull.

three Duncan trees were shaken on March 9, 1962. The trees varied in height from 25 to 28 feet. Data from these tests are given in Table 2.

Valencia Oranges, 1962.—Several tests were conducted on Valencia orange trees in which a specified number of trees were shaken at intervals between April 16 and June 20, 1962. Results of these tests are given in Table 2. Trees in grove No. 1 were 22 feet in height and spaced 25 by 30 feet. Tree shapes were such that it was difficult to reach all the limbs with the shaker. Trees in grove No. 2 were 12 feet high and spaced 25 by 25 feet. The stroke of the unbalanced weight on the shaker was tried at 4, 6, and 7 inches.

Separation Force.—A test was conducted on Valencia oranges to determine the relationship between the separation force and angle of pull. This relationship is plotted in Figure 4. At times, oranges tend to plug when they are detached by pulling parallel (0 degree angle) to the major axis. This plugging is minimized by pulling at an angle to the major axis.

Table 2. Valencia oranges and grapefruit harvested with inertia tree shaker--1962.

Harvest Date	No. of Trees	Shaker Stroke Inches	Brix/Acid Ratio	Removal Per Cent
		Grove No. 1--Valencia		
April 16	4	4	13.91	68.00
April 30	4	4	13.60	70.00
May 8	4	4	--	60.00
May 8	4	6	--	78.60
May 8	4	7	--	72.00
June 4	5	6	18.13	78.00
		Grove No. 2--Valencia		
May 30	6	6	--	83.00
June 6	6	6	--	91.00
June 13	6	6	--	90.00
June 20	6	6	--	93.00
		Marsh Grapefruit		
February 26	3	4	8.32	88.00
		Duncan Grapefruit		
March 9	3	4	8.94	88.73

Discussion of Results

Frequency, stroke, exposure time and the angle of attachment of the shaker to a limb were found to be the major machine design factors affecting fruit removal, while stage of maturity (Brix/acid ratio), tree shape and physiological condition of the tree seem to be the major biological factors. All these factors are interrelated and cannot be entirely separated. In these tests frequency was the only design factor which could be adjusted while the machine was in operation; however, it was observed that an adjustable stroke and angle of attachment might be helpful in adapting the machine to the varying fruit location, stem length, and tree structure. Fruit removal was greater when the fruit was in a turgid condition early in the day or following a rain or irrigation.

Fruit removal varied from 37 per cent to 83 per cent for the oranges in these tests when harvested with the shaker adjusted to a 4-inch stroke of the unbalanced weight (Figure 3). Removal increased in all tests with the increase in Brix/acid ratio of the fruit; however, the rate of increase seemed to be less at the higher ratios. Brix/acid ratio and time from minimum maturity standard are closely related to each other, as shown in Figure 2. This makes Brix/acid ratio adaptable as a basis for comparing removal obtained from different varieties of oranges.

A removal of 88.00 and 88.75 per cent was obtained in Marsh seedless and Duncan grapefruit, respectively. These tests were made at the time of year when the separation force was fairly low and when most of the fruit was being harvested for the cannery.

Late in the 1962 Valencia season the stroke of the unbalanced weight was altered such that a 4-, 6-, and 7-inch stroke could be obtained. The 6- and 7-inch strokes increased removal 30 and 20 per cent, respectively, over the 4-inch stroke (Table 2). The 7-inch stroke made the shaker difficult to handle. This may account for the lower fruit removal obtained with this stroke. Other tests on Valencia oranges using a 6-inch stroke resulted in fruit removal ranging from 83 to 93 per cent. A higher per cent removal might have been obtained in all the tests if a longer stroke had been used throughout.

In the 1961 Valencia test, reshaking the trees gave an increase in fruit removal (Table 1).

This increase could have been due to either a longer period of shaking or a lossening effect resulting from the previous shaking treatment. A longer period of shaking seemed to the major cause of the increase; however, it is rather difficult to separate these factors. In this test, the time required per tree varied from six to eight minutes, of which only one and a half minutes was spent in actually shaking the tree.

Generally, the Brix/acid ratio of the fruit removed by shaking the tree was slightly higher than that remaining on the trees; however, the difference was not considered large enough to allow selective harvesting. Data taken on fruit size showed no difference between fruit shaken off and that remaining on the trees. Theoretically, a difference would be expected; however, variations in fruit location, stem length and tree structure must have influenced the removal differential by sizes.

In tests conducted on oranges, the separation force decreased with an increase in the Brix/acid ratio—the range for all varieties being from 13 to 22 pounds with the force applied parallel to the major fruit axis. The relationship between angle of pull and separation force seemed to be linear except for those angles close to 90° (Figure 4). The effect from bending the stem at those angles may have caused this variation.

Tree and fruit damage are as important in evaluating the merits of any fruit harvesting device as fruit removal. Data collected on decay of fruit harvested in the 1961 Valencia tests showed decay to be 45 per cent higher for fruit shaken off and allowed to fall to the ground than that picked by hand, when stored for three weeks at 60° F. If the fruit had been utilized in the first week, as is done with processed fruit, then the damage would have been less than 13 per cent more for the fruit shaken off. This damage was higher than would be expected when a completed harvesting machine is used. Such a machine would have a catch frame designed to absorb some of the impact force as the fruit is decelerated.

Evaluation of the effect of shaking on tree life and on the succeeding yields will take considerable time. Most of the damage comes from bark breakage and from snapping off young growth in oranges—other than Valencia. Valencia oranges, having young fruit on the trees at harvest time, present a different problem. A fairly good job of selectively harvesting the ripe fruit can be accomplished when the young fruit reaches one-half inch in diameter. The effect of removing some of the young fruit on the succeeding crop is still under study.

Conclusions

The concept of an inertia tree shaker for harvesting citrus fruit has the advantage of operating under present grove conditions with only a minimum change in tree shape. The harvest rate, as related to time per tree, although not as high as desired, was within an acceptable range. Prospects of improvement in the rate by tree shaping and improved machine design look very promising.

Provisions built in the shaker for adjusting frequency, stroke and clamp angle for different grove or even tree conditions would be very desirable. The per cent fruit removal obtained in these tests on oranges were too low for acceptance, especially at the beginning of the harvest. However, the results with a longer stroke machine appear extremely promising for obtaining higher removals.

Evaluation of the horticultural aspect of shaking the trees was not completed. Some damage was done to the bark by the shaker's clamp, which may cause disease problems in the future. This was more severe in Valencia oranges. Improvements in the clamping mechanism are needed to reduce this damage.

Acknowledgments

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