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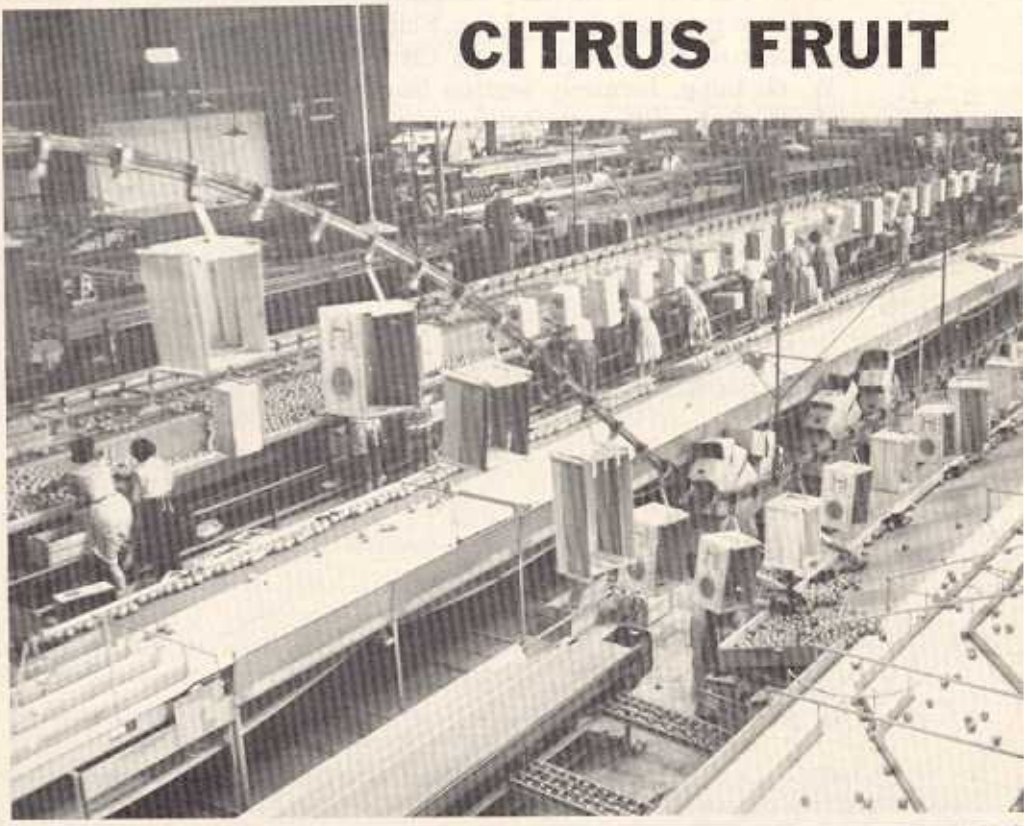
# Better Handling of Florida's Fresh CITRUS FRUIT



AGRICULTURAL EXPERIMENT STATIONS
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## PREFACE

This bulletin has been written by the Fresh Fruit Handling Section of the Citrus Experiment Station, University of Florida, and the research staff of the Florida Citrus Commission at the request of the Florida Fresh Citrus Shippers Association. Dr. W. G. Long, formerly section leader, acted as editor. The authors of the different sections are listed in the contents. Readers may contact the Citrus Experiment Station for further information about better handling of citrus fruits.

This bulletin is dedicated to those who grow, pack, and market better citrus fruit and lead the way for others who will follow.

Cover: An over-all view of a modern Florida packinghouse.

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## SUMMARY

### The Ten Requirements

1. **Pick and handle fruit carefully to avoid injuries.** Injuries (plugging, punctures, cuts, or abrasions) increase green mold and loss by decay.

2. **Degreen under proper conditions if degreening is necessary.** Stem-end rot is increased under degreening room conditions, and stem-end rind breakdown results if the relative humidity is too low.

3. **Wash properly to remove dirt and residues.** It improves appearance.

4. **Apply color-add as recommended if color-add is necessary.** It improves appearance if it's a good crop of fruit.

5. **Apply fungicides to reduce decay.** Save part of the fruit that is usually lost to decay, and make more customers happy.

6. **Wax properly to preserve quality and improve appearance.** Waxing reduces shrinkage and stem-end rind breakdown, and gives fruit a shine to attract consumers.

7. **Handle promptly and properly to avoid stem-end rind breakdown.** Low humidity in the grove or packinghouse can damage much fruit.

8. **Grade and size properly.** It results in a more attractive and better pack.

9. **Precool and refrigerate promptly to reduce decay and preserve quality.** It means money in your pockets.

10. **Increase efficiency of operations to reduce costs.** Presizing, pregrading, proper handling, and suitable containers can reduce costs, increase efficiency. Efficiency, costs, and profits run hand-in-hand.

**REMEMBER THESE TEN REQUIREMENTS FOR GOOD CITRUS FRUIT HANDLING!**

## INTRODUCTION

The quantity of fresh citrus fruit shipped annually is nearly equivalent to the total amount of all deciduous fruits shipped. In some respects the shipment of citrus is the more difficult, because the citrus production areas are usually more distant from the market centers. Florida, California, and Texas produce most of the citrus, but deciduous fruits are produced throughout the United States. The long trip involved in marketing citrus fruits requires careful handling in the packinghouse to insure good condition on arrival.

In an average season, appreciable quantities of the citrus fruit shipped to market are lost through decay. Rough handling, improper degreening, and other practices increase the amount of decay. Through proper handling and packing, this loss can be reduced and the appearance of the fruit improved so that it appeals more strongly to buyers and consumers. Fruit sales, like grocery sales, must be on a repeat basis if they are to be profitable.

The purpose of this bulletin is to point out and explain the best handling and packing methods in the hope that a better product may be marketed. The end result will be continued demand, which is so vital to the economy of the citrus industry. This will mean more profit to growers, packers, and shippers, and better quality citrus fruits for the consumer.

## FIELD HANDLING METHODS IN COMMON USE IN FLORIDA

**Harvesting.**—Citrus fruits are harvested either by pulling or by clipping from the tree. The rind of tangerines is often damaged around the stem end if they are pulled, so tangerines are usually clipped. Clipper cuts and long stems that puncture other fruits should be avoided because they cause increased green mold decay. Pulling usually decreases the amount of stem-end rot, since the flower calyx (button) is removed. Pulling requires less labor, and it is faster. Fruit that is pulled, however, is more subject to green mold decay.

The pulled or clipped fruits are placed in a canvas picking bag which the picker carriers over his shoulder. The bag should be carried carefully to avoid bruising the fruit against the ladder. The bottom of the bag opens, so that the fruit can be emptied into field boxes, pallet boxes, carts, baskets, or loaders.

The bag should be lowered to the bottom of the container, so that the fruit does not drop and bruise as the bag is raised to empty it. Pickers should wear gloves to reduce cuts and injuries to the rind.

**Handling in Field Boxes.**—The standard field boxes are usually made of cypress, but other woods may be used. Size is specified by the Florida Citrus Code of 1949, as amended—601.86:

> All field boxes used in the purchase, sale or handling of citrus fruit from or for the grower by a citrus fruit dealer in the state shall be of the uniform standard size of thirty-one and one-half inches long, thirteen inches high, and twelve inches wide, inside measurements, and shall be divided into two compartments by a center partition of at least three-fourths-inch thickness; and each of these compartments thus created shall have a cubical capacity of not to exceed twenty-four hundred cubic inches.

An empty box weighs about 17 pounds. When full, it will weigh from 100 to 120 pounds, depending upon fruit size, variety, and quality. Field boxes were designed to hold enough fruit to pack out a full 1⅗-bushel box. However, they will not pack out to a 1⅗-bushel box if the quality is low or if the field box is not full. The desire for a high "pack out" frequently results in filling field boxes too full. Crushed or cut fruit is often the result. Sales by weight discourage this practice.

**Handling in Pallet Boxes.**—Bulk boxes or bulk bins are usually about 48 inches square and 32 inches deep (outside). They are usually made of wood, but some are reinforced with sheet metal or angle iron. The usual capacity is 10 to 12 boxes (or approximately 1,000 pounds) of oranges. Pallet boxes weigh from 130 to 258 pounds, depending upon the materials used in their construction.

Fruit is placed in the pallet boxes by the picker. A tractor with a forklift loads the pallet boxes on flatbed trucks or semi-trailers. They are removed at the packinghouse with a forklift and placed in degreening rooms or emptied directly onto the packinghouse line. Pallet boxes are ideal for holding fruit during degreening or after processing.

The cost of pallet box handling is lower than field box handling. Injury to the fruit is about the same, and degreening seems to be no problem. Less labor is required, and operations may be more efficient.

**Bulk Handling.**—Fruit is picked into 20-box carts, 10-box expanded metal baskets, or bulk trucks and then transferred

with highlift trucks or vertical lift elevators to semitrailers. By use of baffles and padded floors, injury to the fruit is greatly reduced. The semitrailers are run onto a tilted ramp, and the fruit is unloaded through the side or tailgate onto a conveyer belt. Fruit can be presized and pregraded before passing into the bulk coloring bins for degreening or storage. Fruit is released from the bottom of the bins onto a conveyer belt which connects with the packing lines.

Bulk handling saves 6 to 11 cents per box in handling costs over field box methods, largely because of greater efficiency and reduced labor. This method permits presizing and pregrading before degreening, which increases the capacity of the packinghouse early in the season. The main disadvantage appears to be the cost of the change-over from a field box to a bulk handling operation.

Combinations of bulk field handling and pallet box packinghouse handling have been used. Degreening in pallet boxes uses space more efficiently and requires less overhead than bulk degreening rooms. When degreening is not required, bulk handling is employed throughout the whole operation. This points out the very important fact that a packing system should be designed to fit the conditions—present and future.

## DEGREENING AND NATURAL COLOR

**Fruit Color: Its Changes and Significance.**—In the fall, citrus fruits begin to change color. Spots on the side toward the light begin to lose their green chlorophyll pigments, unmasking the yellow pigments that have been there all along. At this time the yellow pigments begin to increase in amount. The spots increase in size and number and unite until the entire surface of the fruit is yellow.

The change in color is associated with cool nights (particularly below 50° F). The temperature required to stimulate loss of green color of fruit on the tree is lower for oranges than for grapefruit. Fruits of some varieties, such as grapefruit and Hamlin and Parson Brown oranges, mature internally but do not develop a satisfactory color until cool weather, which usually occurs in early December. Since the natural development of fruit color usually occurs after the beginning of the harvesting season, fruit must be treated to remove the green color (degreened), allowing the natural orange or yellow color to predominate.

If green fruits are picked and placed in storage at 50°, 60°, of 70° F, they will lose their green color in 1 to 4 weeks, depending upon maturity and the storage temperature. A temperature of 60° F is superior to 50° or 70° for degreening in storage or transit.

The length of time required to degreen a fruit depends upon the degree of natural color break and maturity. The lighter the green color and the more mature the fruit is, the less time is required to diminish the chlorophyll to a tolerable level. Actually, most fruits, if not all, never lose all their chlorophyll. Very sensitive color measuring instruments show some chlorophyll still present long after the eye can no longer see it.

In the late varieties of oranges and in grapefruit, some chlorophyll is produced in the rind when vigorous vegetative growth resumes in the spring. This phenomenon is called "regreening." Florida Valencia oranges, Pope Summer oranges, and grapefruit usually regreen. Inside fruits which are shaded by the leaves never entirely lose their green color; this should not be confused with regreening. These fruit actually become a little greener when regreening occurs.

Research results show that within any given load of fruit, a strong relationship exists between color and many other desirable qualities, such as taste and Brix. Color was measured by both reflected and transmitted light; in most determinations, a stronger correlation was found when reflected light was used. These results point out a possibility of color sorting for quality in addition to sorting into different color lots for efficient degreening. Color sorting for degreening has been practiced on the pregrading conveyer of one or two houses for many years. It is a sensible and efficient practice with some crops of fruit.

**Ethylene Degreening.**—The consumer expects citrus to have a color characteristic of the specific variety. For this reason, poorly colored mature fruit is treated with ethylene gas in rooms referred to as degreening or coloring rooms. (The term "degreening" is preferred.)

The loss of citrus fruit due to mold decay is less during the degreening part of the season. Some healing action of the fruit closes superficial injuries under conditions found in degreening rooms. This prevents entrance of mold spores. Holding fruit at degreening room temperature and humidity but without ethylene is called curing. The growth of stem-end rot organisms is speeded up in the degreening room. Usually, degreened fruit will have less mold decay but more stem-end rot. The

longer fruit remains in the degreening rooms, the greater the total decay loss.

Degreening rooms should be tight enough so that the proper concentration of ethylene gas, 1 part in 50,000 parts of air, can be maintained. Ethylene gas is purchased in gas storage cylinders and piped into the degreening rooms through gas-tight lines.

Ethylene is introduced into the room by the commonly used "trickle unit" illustrated in Figure 1. To reach the initial concentration rapidly, the water column is raised to 3 inches on the scale and left there 1 minute for each 100-box capacity of the room. After the required concentration is reached, the rate is adjusted to 10 bubbles per minute per 100-box capacity of the room for the remainder of the degreening period.

Forced circulation of air in degreening rooms must be sufficient to provide perceptible movement in all portions of the room. Proper air circulation requires adequate fan capacity. This varies between 625 and 1,500 cubic feet per minute per 1,000 cubic feet air volume of the room. Ventilation ducts should be provided so that a regulated amount of fresh air is added continuously to keep the concentration of carbon dioxide below 1 percent. If carbon dioxide gas is allowed to build up, degreening slows and stops. Adjustable fresh air vents should be placed in all gas-tight degreening rooms so that a constant supply of fresh air is introduced when the room is in operation. Proper adjustment of fresh air vents makes it unnecessary to air degreening rooms. Gas-tight degreening rooms without fresh air vents must be aired several times daily. Canvas degreening rooms usually have enough natural exchange of fresh air so that air vents are not necessary.

Early in the season, citrus fruit may be degreened for as long as 72 hours. Longer degreening is not a desirable commercial practice. Fruit should be held in the degreening room for only the minimum time necessary to get the desired color. Twelve hours is the shortest practical degreening time for more fully colored fruit.

Degreening rooms cannot be operated above 85° F dry bulb reading with applied heat (Florida Citrus Commission Regulation 13). The wet bulb reading should be 82° to 83° F, which gives 88 to 92 percent relative humidity. Humidity is usually controlled manually. When the temperature is below 85° F, moist steam can be used to increase humidity. When the tem-

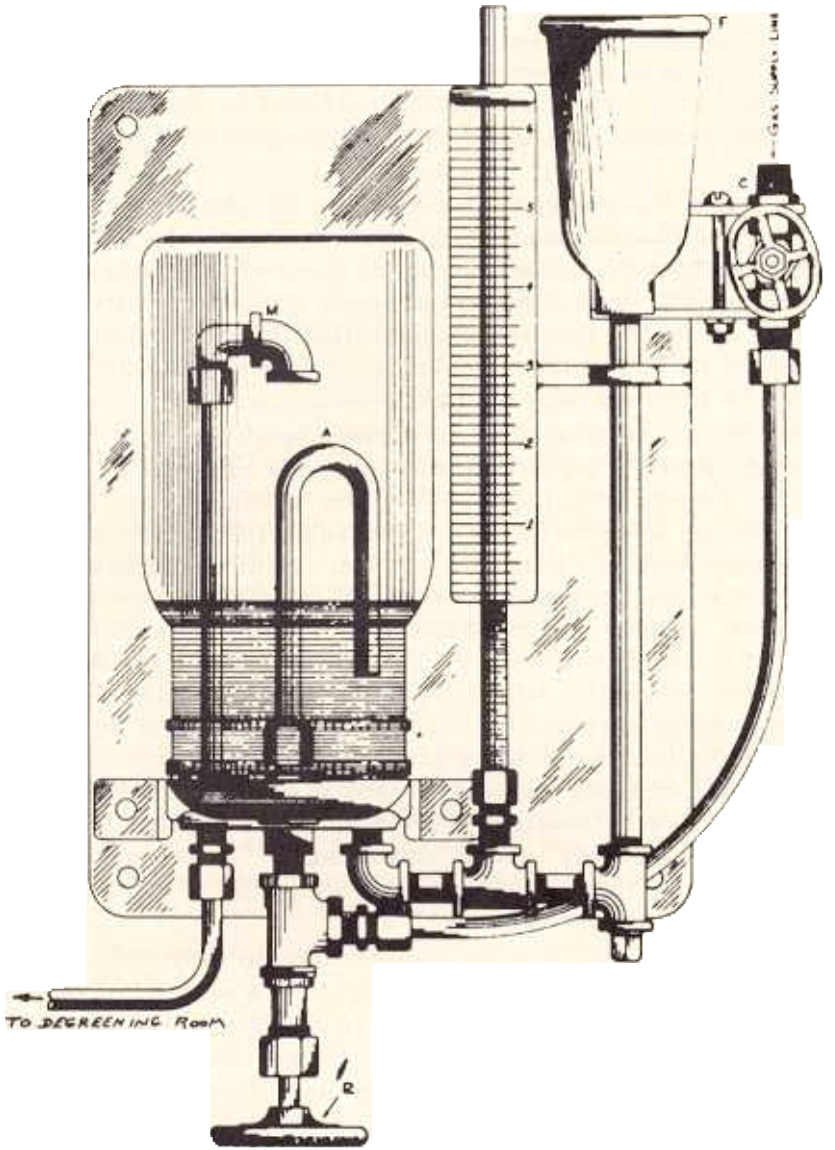



Fig. 1.—"Trickle unit" used for dispensing ethylene gas to a degreening room. Water or white oil is introduced through the funnel "F" until the level is as shown. Ethylene from the main supply line enters through the cut-off valve "C" and is regulated by the needle valve "R." The delivery pipe "A" is inverted so that the ethylene has to bubble through the water. The metering orifice "M" causes a back pressure, resulting in a rise in the manometer column proportional to the rate of gas flow. (Courtesy Food Machinery and Chemical Corporation.)

perature is higher, water mist should be used to increase humidity. Place water mist nozzles so the mist is carried throughout the room by the fan.

Excess ethylene may injure the rind of citrus fruits. Tangerines and Temple oranges are especially sensitive to ethylene burn. This injury is not usually noticeable until several days following ethylene treatment (Figure 2). Ethylene injury is usually increased by handling, particularly brushing. Gassing of Temple oranges should be avoided. Only tangerines that have a good natural color break should be picked and gassed.

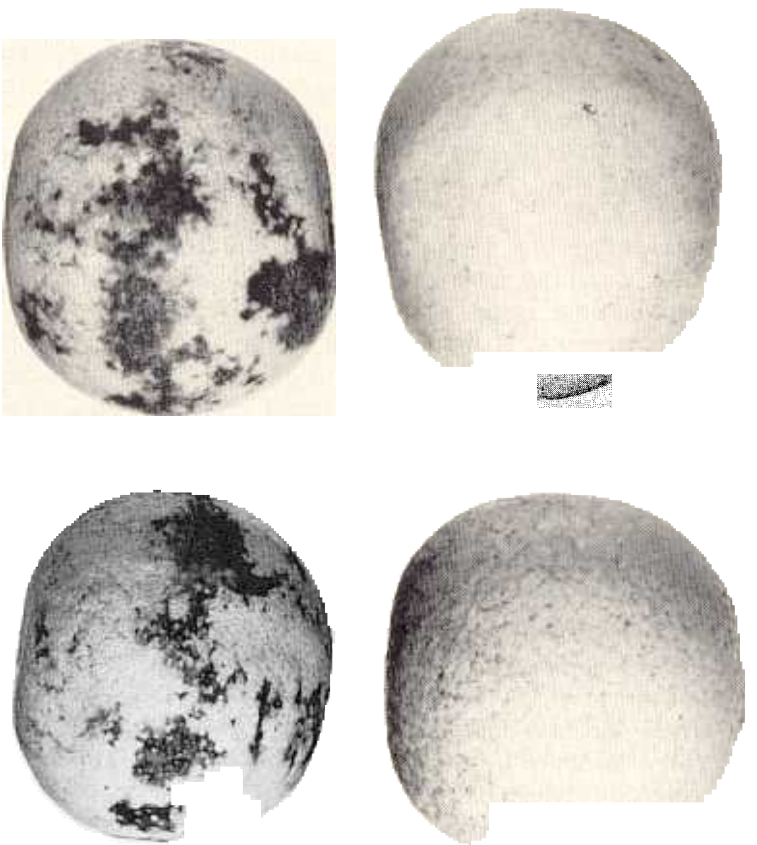


Fig. 2.—Blemished fruit was gassed 68 hours at a low average relative humidity (68 percent). Unblemished fruit was from same lot but not gassed. Injury became evident 5 days after picking.

For more details on citrus degreening, refer to the University of Florida Agricultural Experiment Stations Bulletin 620, "Degreening of Florida Citrus Fruits," by W. Grierson and W. F. Newhall.

## CONVENTIONAL PACKINGHOUSE LINES AND EQUIPMENT IN FLORIDA

A packinghouse line should be designed so that the largest amount of fruit packed is not greater than 90 percent of its capacity. Also, a greater number of operating days and more continuous utilization of the packinghouse line lead to greater efficiency and a lower packing cost per box. The choice of handling systems, i.e., bulk, pallet box, field box, or combination, depends upon the size of the groves to be harvested and their location in relation to the packinghouse.

Presizing and pregrading to remove cannery fruit are desirable before the fruit enters the degreening bins or rooms, or the packing line.

The packing line begins with the dumping operation, i.e., dump belt, dumping machines, or the belt from the bulk rooms or bulk unloading ramp. Sometimes the fruit is conveyed to a soak tank, where it is immersed in water or a cleaning solution for a few minutes. In most cases soak tanks are not necessary for good cleaning, so they are no longer recommended, although many older houses still have them. A fruit cleaner is applied as a foam as the fruit enters a transverse brush washer. The loosened dirt is rinsed off with a cold water spray. Fruit passes over a water eliminator and enters the color-add tank or bypasses it. The color-add tank also may be used for Dow-Hex treatment (but not in combination with color-add). The fruit enters either the water waxer followed by the drier, or the drier and then the solvent waxer. Fruit is dried and brushed (drier-polisher) ahead of the solvent waxer, because such pretreatment is essential for maximum gloss of the wax coating.

The "color-added" stamping machine is usually placed after the waxer and drier. The fruit ready for packing passes over a grading belt and is hand-sorted into the desired grades. The fruit is sized with a central (master) belt, chain, or a bin-type sizer and packed from roll-board stations, bins, bagging machines, count-pack, or similar machines. Since most houses pack in many containers, i.e., half and full wirebound boxes, including half straps, cartons, "Duralugs," fiber mesh bags, and poly-

ethylene (poly) bags, and other consumer-size containers, the traffic distribution to and from packing stations is a complex problem. While it would probably be difficult, it would greatly simplify packinghouse operations to standardize on two or three containers. Packing, closing, distribution, transporting, and marketing would also be a much simpler task.

The packed containers are handled by conveyer, pallets, fork-lifts, or hand trucks. The method that is used depends upon the scale of operations.

For large scale operations it is advantageous to have two lines, a large one for oranges and grapefruit, and a smaller one designed specially for tangerines, tangelos, Temples, and other tender varieties. In periods of heavy harvest, the second line may be used for the overflow of oranges and grapefruit.

Precooling and refrigeration are very desirable for citrus. Decay control, shrinkage control, and quality are maintained for a longer time. Suitable refrigeration services (ice, fans, vents) should be provided in transit. Probably one of the greatest advances in transportation has been the "piggy back," in which specially constructed semitrailer trucks are loaded on railroad flatcars for long distance shipping. Its great virtue is reliable refrigeration, but stacking patterns and direction of loading are very important. Hydrocooling and poly bags are not nearly as effective in maintaining freshness and quality unless continued refrigeration is provided. Since citrus does not need ripening after harvest, refrigeration should be provided from the time it is packed until the last fruit is used from the consumer's refrigerator.

## PRESIZING AND PREGRADING

**Presizing** removes the small and large fruits that are not saleable as fresh fruit, or enables selection of certain sizes for the orders on hand (Fig. 3). The advantages of presizing are that sized-out fruit brings a higher field-run price than packinghouse eliminations (however, they are often mixed together), and the effective size of the packinghouse is increased.

**Pregrading** results in economy and greater efficiency of operation (Fig. 4). The sound fruit that is graded out because of superficial defects also brings higher field-run prices. The culls (splits, rots, and cracked fruits) are removed, thus eliminating an important source of infection and saving many other fruits from being lost through green mold rot.

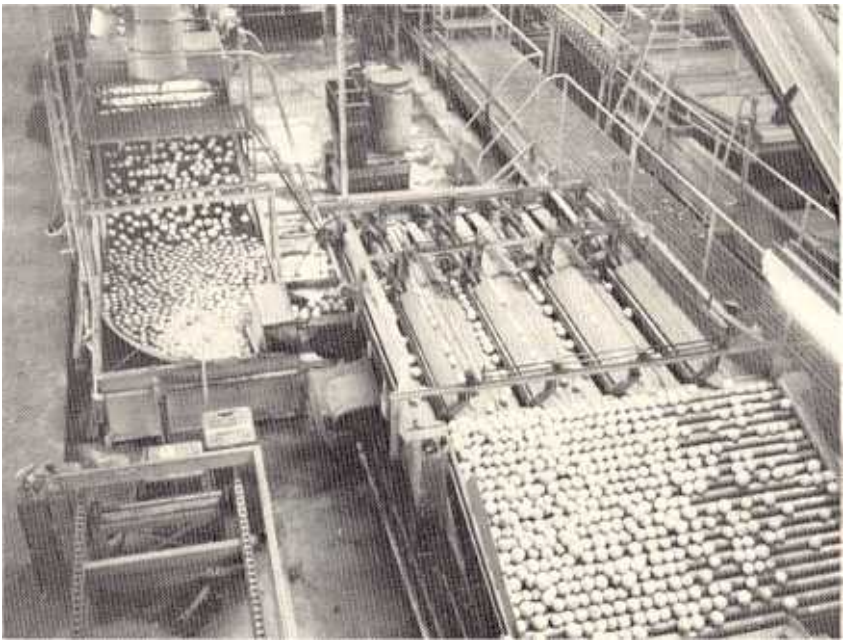


Fig. 3.—The presizer often follows the pregrader (Fig. 4), but this should be reversed. Note the soak tank and washer in the left background.

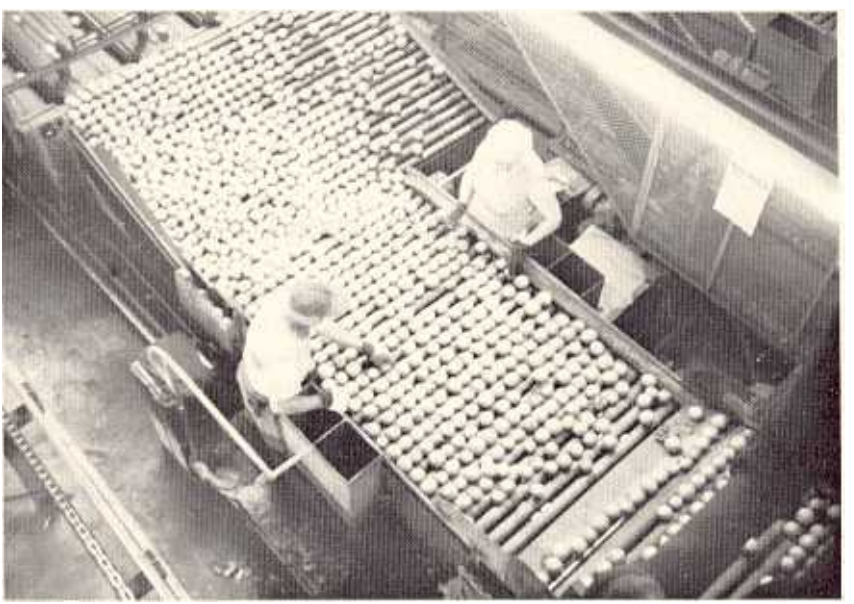


Fig. 4.—The pregrading set-up is often a simple one, but it improves the operations in many ways.

The use of presizing and pregrading is an efficient practice. Most packinghouses grade and size-out at least 25 percent of their fruit. If this is done by presizing and pregrading, the effective capacity of the house is increased 25 percent. In addition, water, electricity, soap, color-add, and wax are conserved, and degreening or storage space is better utilized.

## STEM-END RIND BREAKDOWN

There are many causes of rind pitting and breakdown in citrus fruits. One type called stem-end rind breakdown (Fig. 5) is frequently found on oranges in the market place, but is rarely observed in the packinghouse. It begins to develop 5 to 7 days after picking and is primarily due to drying out of the fruit (Fig. 5). The symptoms are shriveled and pitted areas, usually

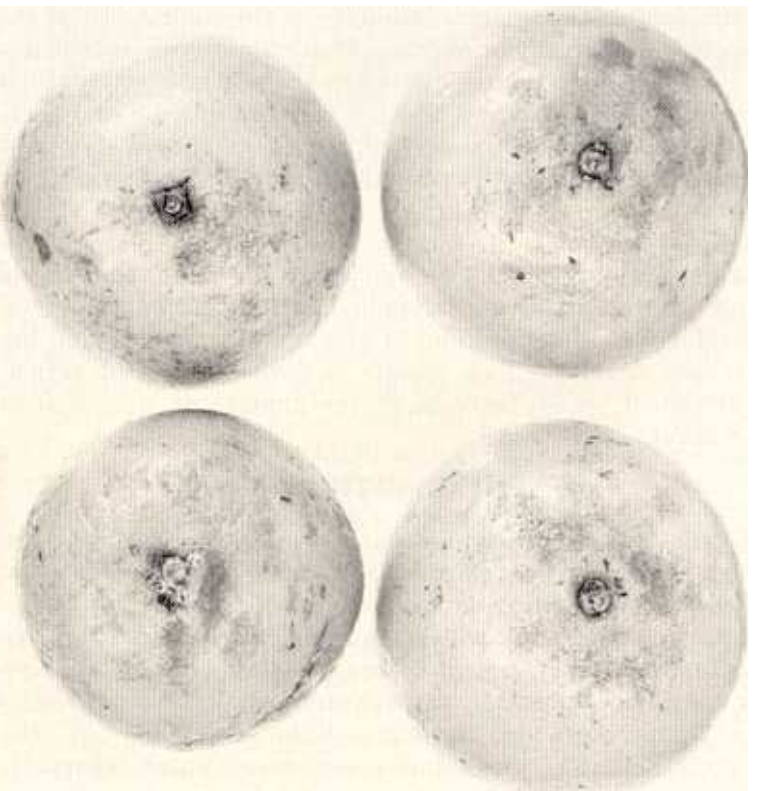


Fig. 5.—Stem-end rind breakdown of Pineapple oranges.

on the stem end of the orange, which give the fruit an overmature look and result in increased spoilage. Stem-end rind breakdown is also known by other names such as brown-stem, stem-end pitting, and stem-end aging. The Pineapple orange is the most susceptible commercial variety grown in Florida, but all the orange varieties show this pitting to some degree, depending on the season and how the fruit is handled. Fruit from different groves and different pickings from the same grove may vary in susceptibility. Grapefruit varieties and tangerines have not been known to develop this type of defect.

Stem-end rind breakdown may develop when oranges are: (1) degreened at lower than recommended humidity; (2) allowed to remain on the packinghouse floor for a day or more before packing, particularly when the humidity is low; or (3) subjected to any delay in handling between picking and waxing.

To prevent the development of stem-end rind breakdown, oranges should be packed as soon after picking as possible. During degreening, the relative humidity of the coloring room should be kept at 85 percent or above. This humidity is obtained with a spread of 2 or 3 degrees between the wet and dry bulb thermometers. When there is a delay between picking and packing, and the fruit does not need degreening, it should be placed in a degreening room and the relative humidity kept at 85 percent or above with fans operating. No ethylene or heat should be added.

A good wax film must be applied to the fruit following processing. If too little wax is applied or if it is applied unevenly, particularly to the stem end of the fruit, stem-end rind breakdown may develop. This results in down-grading or refusal of the shipment, or an increase in the amount of spoiled fruit at the market.

## WASHING CITRUS FRUIT

Citrus fruits are usually washed in brush washers using a cleaner of some type, followed by a clear water rinse to remove the loosened dirt, oil, residues, scale deposits, etc. In older packinghouses, a soak tank was sometimes placed before the washer to soften dirt, resides, etc., before washing (Fig. 6). The soak tank may contain water, or a water conditioner or soap (detergent) may be added to help wet the fruit and "cut" the oil and scale deposits. Soak tanks can cause water injury if the tank design permits fruit to accumulate in corners and remain stationary for long periods of time, or if the line is shut down

and fruit is left standing in water or solution. Soak tanks are not usually recommended because of possible water injury and because they are unnecessary for good cleaning, unless the fruit is very dirty or oily.

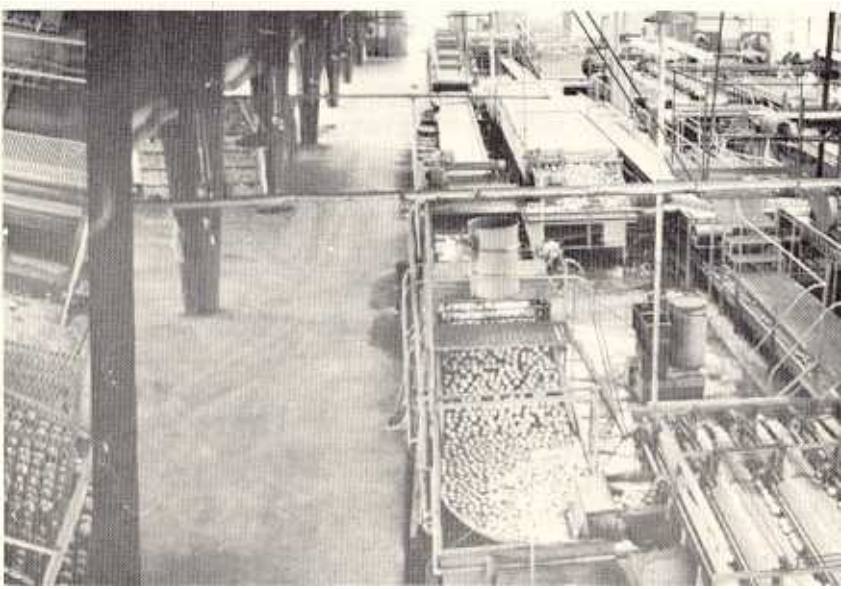


Fig. 6.—Soak tank in center foreground and fruit washer with rinse-off and water eliminator. In the background are shown the "bypass" belt on left, color-add tank on right, and two types of driers in distance.

Citrus cleaners usually consist of a soap plus a water conditioner such as soda ash or trisodium phosphate. A water conditioner is needed if the water is hard. Detergents usually do not need an additional water conditioner. However, detergents do not break down in septic tanks as soap does, and after a period of years they may cause malfunction of the tank. Most commercial citrus cleaners contain a soap or detergent, water conditioners, and additives that help do a better job of washing. Dowicide A-hexamine solution may replace the cleaner (see decay control section).

The only washer in use today is the transverse brush washer. The brushes may be Tampico or palmetto fiber, but in recent years synthetic fibers such as nylon, saran, polystyrene, polypropylene, vinyl chloride acetate, tynex, and other polymers have come into common use. The fibers should be of proper size and softness to remove dirt but not stiff enough to injure fruit. Brush speed should not exceed 200 rpm. The recommended rate

of climb for the washer is ¾ inch per foot. In order to prevent fruit injury, brushes should be inspected and replaced promptly if worn.

The cleaner is usually foamed onto the fruit from a shallow pan by means of compressed air, or sprayed over the fruit with the aid of a centrifugal pump (Fig. 7). After scrubbing on the brushes, the fruit is rinsed under a spray of clear water (Fig. 8). The excess water is removed by brass or sponge rubber eliminator rollers or a slat or roller elevator before the fruit enters the drier (Fig. 9).

**Driers** are usually one of two types: (1) slat or roller conveyers over which heated air from a bank of steam pipes or radiators is blown by a series of fans (Fig. 10), or (2) transverse brush driers which contain 40 to 60 horsehair or soft synthetic bristle brushes instead of rollers or slats. Prolonged brushing, high speed brushing, stiff bristles, and high temperatures while drying should be avoided, because the amount of rind injury (oleocellosis and stem-end rind breakdown) and decay is increased, while shine may be decreased. Drier brushes may remove scale insects not removed by the washer brushes. The drier brush speeds should not be over 150 rpm, and the lowest amount of heat necessary to dry the fruit should be used.

Fig. 7.—The sudser-type washer with rinse-off and water eliminator.

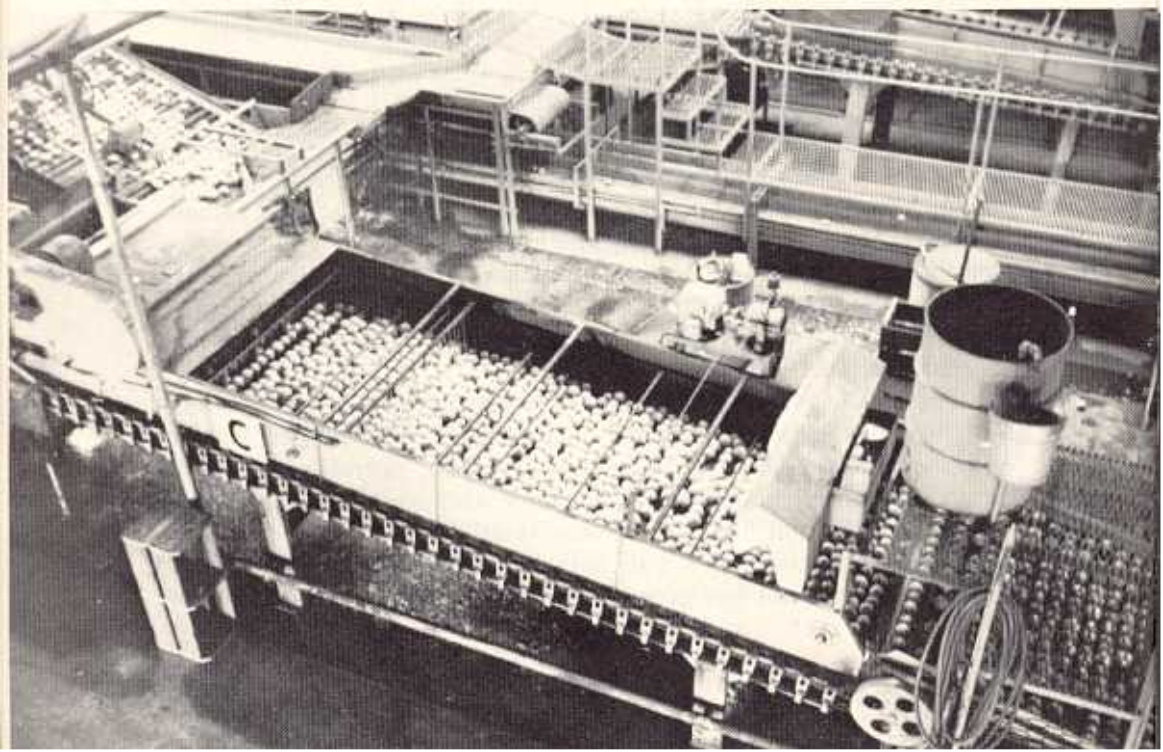


Fig. 8.—The "rinse-off." Note that the fruit are well sudsed before being rinsed.

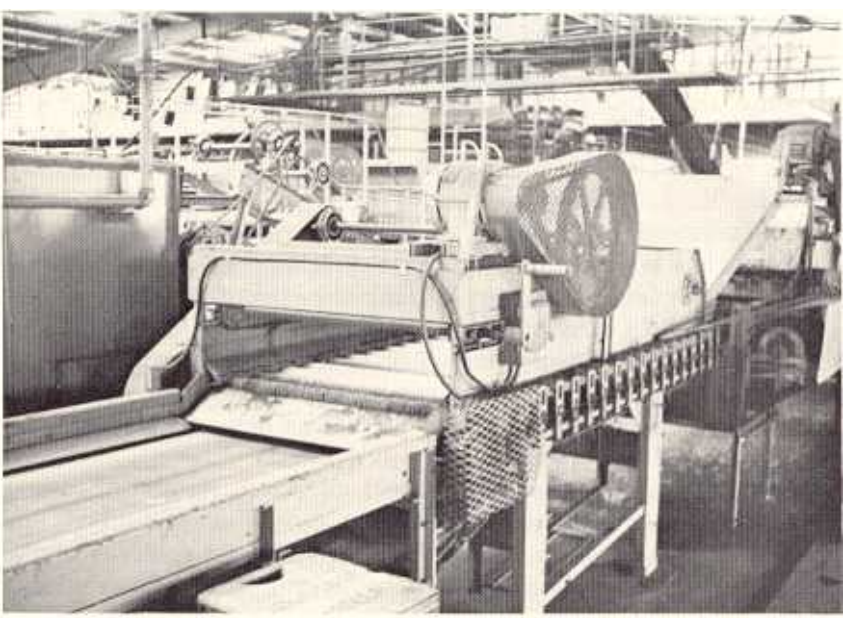


Fig. 9.—The water eliminator removes excess water from the fruit before it enters the drier, color-add tank, or bypass belt. Note "foam" rollers on the bed of the eliminator.

Polishers containing brushes are sometimes used before solvent wax is applied. The brushes should be soft and operated at a speed of 150 rpm or less. Water waxes are applied ahead of the drier, and polishers do not improve the shine, since most of them are self-polishing. Slat or roller conveyer driers are often used.

Fig. 10.—Fruit entering the drier from the color-add tank.

## COLOR-ADDING

Early oranges in Florida mature before nighttime temperatures are low enough for the peel to develop a good orange color. Late oranges tend to regreen during the spring flush of growth. Degreening with ethylene removes the green color due to clorophyll but leaves the peel a yellow or very pale orange. Since many customers believe that oranges should be orange in color, the process of color-adding with a dye was developed to improve the eye-appeal and marketability of oranges.

The color-add process is subject to strict regulation under the Florida Citrus Code of 1949, as amended, and Food and Drug Administration to insure that the consumer receives wholesome, mature fruit with good keeping qualities. Color-adding is permitted for oranges, Temple oranges, and tangelos, but is prohibited for grapefruit and tangerines. Maturity standards for fruit to be color-added are higher for juice content, total

solids, and Brix/acid ratio than the minimum required for natural-color fruit. Samples of coloring materials and details of formulation and process must be submitted to the Florida Department of Agriculture for analysis and approval prior to sale to insure that materials which are harmless to fruit and consumers will be used. The color characteristic of good natural-color fruit may not be exceeded, and each fruit must be stamped with the words "Color-Added" (50% Tolerance, 3/32-inch type). Packages must also be labeled. Time and temperature of treatment are limited by law (Regulation 12, F.C.C.) to protect keeping quality of the fruit.

Only one dye is currently approved by the U. S. Food and Drug Administration for coloring citrus fruit. This is 1-(2,5 dimethoxyphenylazo)-2 naphthol, which is more commonly known as Citrus Red No. 2. An official tolerance of 2 ppm has been established based on the weight of the whole fruit. Residues are easily determined by the method devised by Ting for Red No. 32, the dye formerly used. This method consists of washing the dye from the fruit with chloroform and calculating the concentration by comparing light absorption at 520 m$\mu$ with that of a standard dye solution.

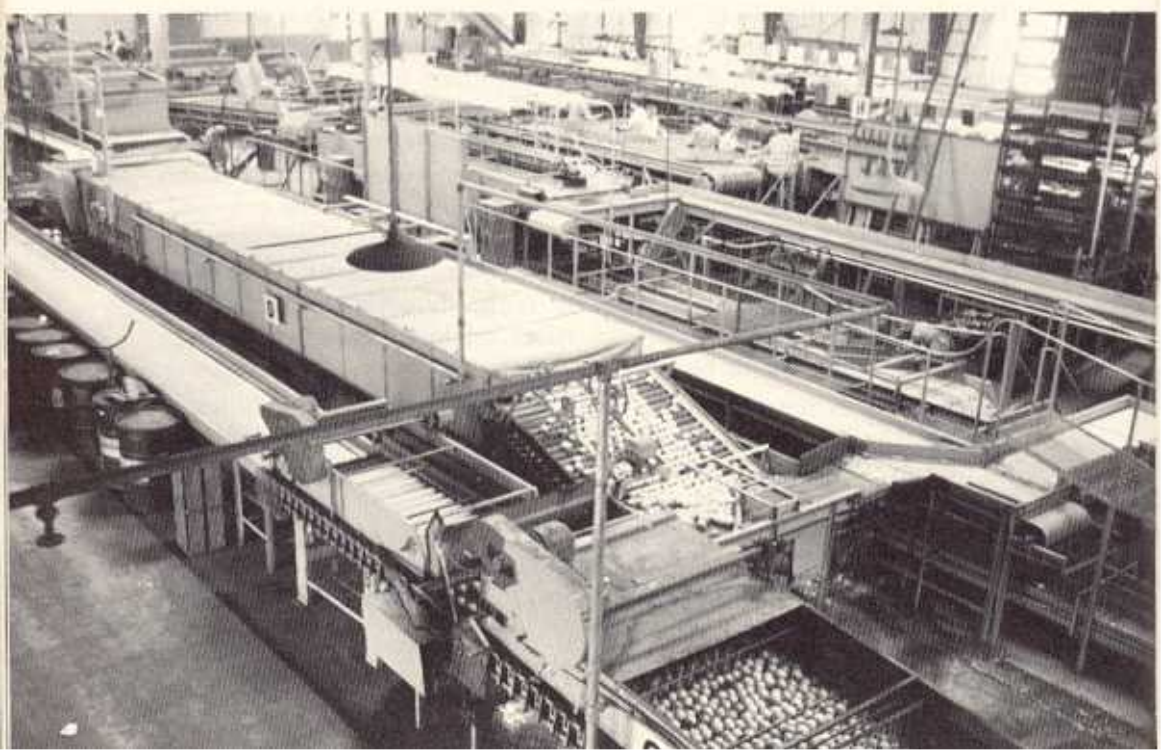
Numerous patents have been issued for processes and formulations for coloring citrus fruits, but those currently used commercially are all basically similar. The oil-soluble dye, Citrus Red No. 2, is dissolved in an organic solvent, and this solution is emulsified in water for use in coloring fruit. Solvents and emulsifiers vary from one process to another, but in all methods the fruit is treated with a dye emulsion, and the color is deposited in the oil cells of the peel. Stability of the emulsion is critical in the color-add process. If too much emulsifier is used, the dye remains in the emulsion and the fruit is not well colored. Too little emulsifier results in breaking of the emulsion, which leads to uneven color and injury to the peel of the fruit. For this reason, field residues and broken fruit should not reach the color-add tank, since they may react with the emulsifier and cause the emulsion to break.

Equipment used to apply color-add emulsion to fruit follows the washer in the packinghouse line and is quite standardized in design (Fig. 11). The color-add emulsion is contained in a tank equipped with a thermostatically controlled steam coil to maintain the desired temperature. The fruit travels above this tank on a roller conveyer which rotates the oranges to assure even coverage by the color-add emulsion. A centrifugal pump

raises the emulsion to a flood pan above the conveyer, and numerous holes in this pan distribute a continuous flow of color-add emulsion over the fruit passing beneath. Excess emulsion passes through the conveyer back into the tank. Temperature of treatment is controlled by the thermostat connected to the steam valve, and duration of treatment depends on the speed of the conveyer. Maximum legal limits for treatments are 4 minutes at 120° F for oranges and 2½ minutes at 115° F for Temple oranges and tangelos. After the fruit leaves the color-add tank, it is rinsed with a water spray to remove excess emulsion and cool the fruit.

Color concentrate should be kept tightly covered and stored without being exposed to extreme temperatures. Manufacturer's directions for making up the color-add bath and maintaining concentration should be carefully followed. A proportioning pump coordinated with the dump rate is a good way to correct for depletion of color in the bath. Flood pans and screens should be cleaned at least daily. Fruit should be well washed and excess water eliminated before reaching the color-add applicator, and decayed or broken fruit should be removed. Green fruit cannot be dyed to give a satisfactory orange color.

Fig. 11.—Fruit leaving the washer and entering the "color-add" tank, where a dye solution is applied to the fruit. Note the "bypass" belt on the left for natural color fruit.



## WAXES

Citrus fruit are waxed to replace the natural wax removed in washing, to reduce shrinkage and weight loss, and to increase consumer appeal by making the fruit shine. A good wax deposit may provide shrinkage control between 40 and 50 percent of the weight lost by unwaxed fruit of the same lot. The natural wax on citrus fruit gives about 20 percent shrinkage control compared to washed, unwaxed fruit. Greater than 40 to 50 percent shrinkage control can be obtained, but the heavier wax deposit required interferes with the normal respiration of the fruit, and off-flavors may develop. Drying time is also greatly increased for heavier wax deposits.

Two types of waxes are available for use on citrus fruits.

**Solvent-Type Wax.**—The most common wax of this type consists of a coumarone-indene resin dissolved in a volatile petroleum ether solvent. The Food and Drug Administration has established a tolerance of 200 ppm for this resin. Fruit to which solvent-type waxes are to be applied is washed, dried, and usually polished, using soft brushes (such as horsehair) before the wax is applied. The wax is atomized on the dry fruit as it rolls on metal rollers (Fig. 12). Then the waxed fruit is dried on a slat conveyer. This is usually built in two sections so that the fruit makes a half turn as it rolls onto the second section. This exposes all sides of the fruit so that the solvent evaporates quickly, leaving the wax.

The unwaxed fruit passing through the first part of the drier should be on a slat or roller conveyer. Instead, many packinghouses use brushes in both the dryer and polisher. To avoid injury to tender-skinned fruit, brushing should be held to a minimum. The polisher part of the drier usually contains horsehair or other kinds of soft brushes. Some packinghouses have replaced the brushes in the drying operation with a slat conveyer before the solvent-type wax application with satisfactory results. Polisher brush speed should be 200 rpm or less to avoid injuring the peel of the fruit. On separate packing lines for tangerines and other soft citrus fruit, 150 rpm is a better brush speed. Excess drying is harmful, but the fruit must be free of moisture when the solvent-type wax is applied to insure a good shine. Solvent waxes containing fungicides for decay control are available.

**Water Emulsion Wax.**—Waxes of this type are applied to fruit without previous drying. The fruit is washed in the usual

manner, and excess water removed on a roller bed or by water eliminators. The wax is applied either by fixed nozzles or a traveling nozzle. Using either method, the wax is applied as a mist. The fruit is carried under the wax applicator on soft brushes or some type of roller that helps to distribute the wax evenly over the surface of the fruit. Water emulsion waxes can also be applied as a bath in a small tank, but this method is not usually recommended because of the heavy deposit that results.

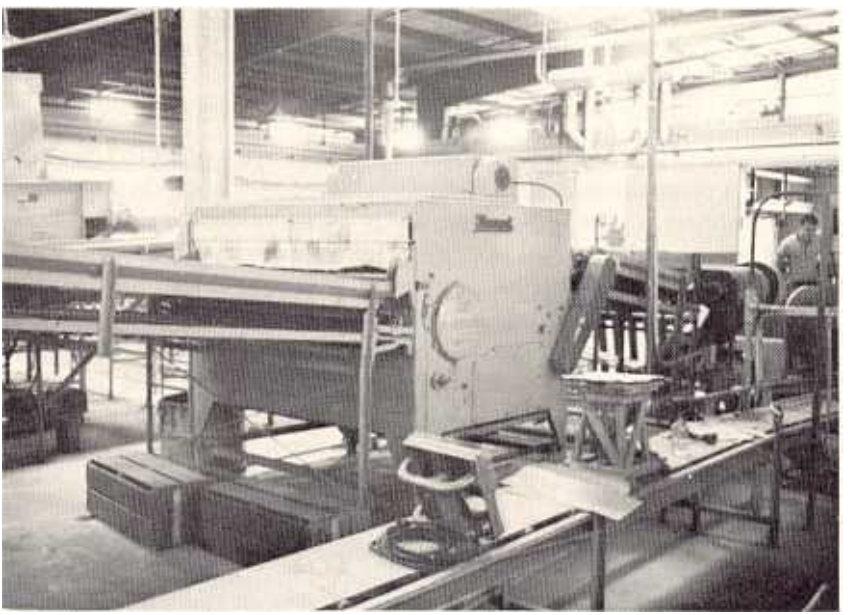


Fig. 12.—A solvent-type wax applicator. Note flue which removes flammable fumes.

The waxed fruit is dried with applied heat on a slat or a roller conveyer. The roller conveyer is installed so the rollers do not revolve except at designated places. The fruit makes at least a half turn during the drying operation, so that all sides are exposed to the heat. Waxes of this type can be used on any citrus fruit but are especially recommended for tender fruit that may be injured by unnecessary brushing. Fungicides are often incorporated in water emulsion waxes.

A good wax, properly applied, reduces moisture loss from the fruit, resulting in a naturally firm-appearing fruit during the marketing and consumption period.

## DECAY CONTROL

Loss from decay is an important economic factor in the marketing of fresh Florida citrus fruits. The average decay loss for a 7-year period at the Citrus Experiment Station was 19 percent 2 weeks after picking. This average included four varieties of oranges gassed and ungassed but not treated for the control of decay and held at 70° F.

Four species of fungi cause nearly all the decay that occurs during the marketing period. Stem-end rot is caused by either *Diplodia natalensis* or *Phomopsis citri* (Fig. 13). The most prevalent mold is green mold, *Penicillium digitatum,* but blue mold, *Penicillium italicum,* is sometimes found on Florida citrus fruit (Fig. 14).

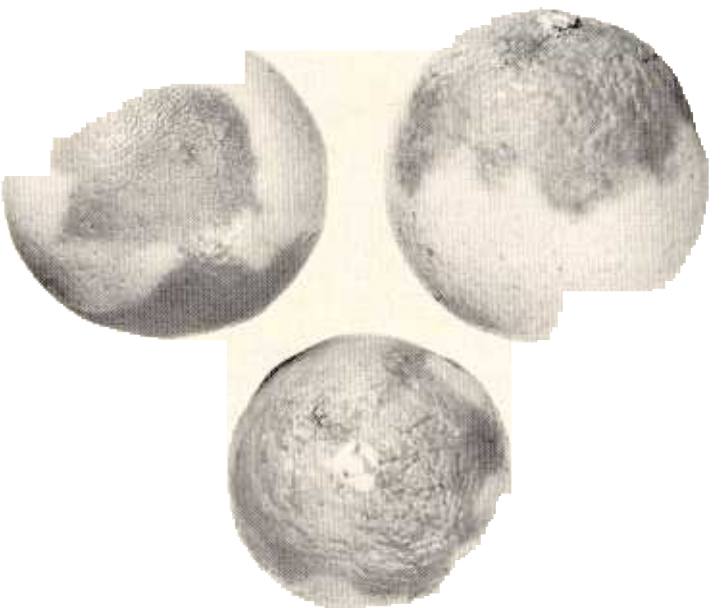


Fig. 13.—Stem-end rot on oranges showing typical symptoms.

The fungi that cause stem-end rot are already in the calyx lobes of the fruit button at picking time. The loss from these two fungi usually does not show up until the second week following picking. Stem-end rot losses are usually heavier during the

degreening period and the warm spring and early summer weather. The types of decay caused by these two fungi are so similar in appearance that they are commercially considered as one form of decay.

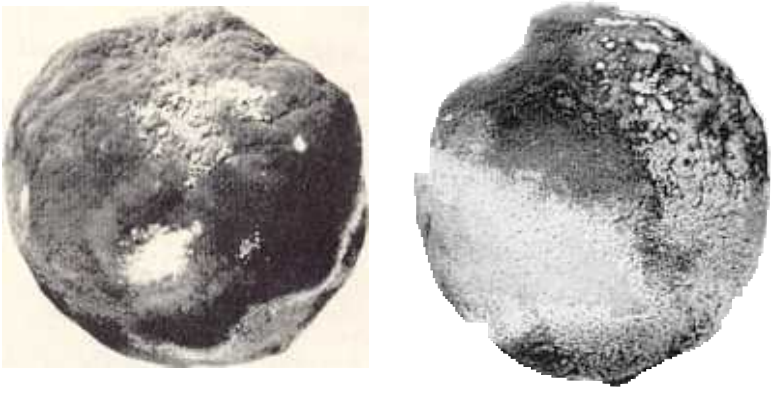


Fig. 14. Green and blue mold rot on oranges.

The molds differ in that they usually enter the fruit only through injuries that occur during the picking, packing, and marketing period and may be evident at any time. Mold losses are usually more severe during January and February.

**Fungicides.**—Most Florida citrus can benefit by the use of fungicides during packing. Those that are effective for Florida citrus and have been approved by the Federal Food and Drug Administration are:

1. Diphenyl (also called biphenyl)—residue tolerance 110 ppm.
2. Sodium *o*-phenylphenate (Dowicide A)—residue tolerance 10 ppm calculated as *o*-phenylphenol.

**Diphenyl.**—Pads impregnated with diphenyl are placed at the top and bottom of 4/5-bushel fiberboard cartons. Two pads contain approximately 4.7 grams of diphenyl. In wooden containers, diphenyl-treated liners that completely enclose the fruit can be used. The odor is objectionable, but it is lost when the fruit is exposed to air for several days.

Diphenyl should be used with polyethylene bags of citrus in master containers. The pads are placed in the bottom and top

of the master container, not in the bags. The decay-inhibiting effect of the diphenyl usually lasts for at least a week after the pads are removed.

**For good decay control, the diphenyl pads or liners must be fresh.** Keep them sealed in glassine paper or foil when not in use. When it is necessary to keep diphenyl pads for an extended period, they should be kept in a sealed package under refrigeration.

**Sodium o-phenylphenate.**—The trade name of this material is Dowicide A. The solution is made safe to use on fruit by adding hexamine (hexamethylenetetramine) before treating citrus fruit. Caustic soda (NaOH) is added to keep the solution highly alkaline (11.5-12.2 pH). Dowicide A-hexamine can be used in the packing line in one of three ways:

1. Dip treatment.
2. Flooded on in a color-add applicator.
3. Flooded on washer brushes sufficient to wet the fruit thoroughly (used in place of soap).

The treating solution is made using 2.0 percent Dowicide A, 1.0 percent hexamine, and 0.2 percent caustic soda in water.

The temperature of the Dowicide A-hexamine solution should be about 90° F while treating fruit. The temperature should never go above 95° F. All fruit must be rinsed with clear water after the treatment. A Brix hydrometer, standardized at 20° C, is used to measure the strength of the solution. A solution of the right concentration for treating fruit will have a Brix reading of 2.7°.

The recommended period of immersion is 2 minutes when treating by the dip method. The length of treatment is 3 to 4 minutes when the fruit is flooded in a color-add tank. The length of treatment when fruit is flooded on the washer brushes is set by the construction of the washer, but it should not be less than 2 minutes. Fruit may be burned if left in contact with Dowicide A-hexamine solution for more than 5 minutes.

**Dowicooling.**—Good decay control has been obtained using 0.1 percent Dowicide A at pH 10.5 in the water of a hydrocooler.

**Cleaning Equipment.**—Dowicide A-hexamine treating equipment can be cleaned at the end of the packing season using a 5 percent caustic soda solution (NaOH) at a temperature of 100° to 120° F. Circulate this solution through the pipes, flood pans,

etc., for 10 to 15 minutes. Use it to scrub surfaces coated with Dowicide A-hexamine deposits. Rinse all surfaces where caustic soda was used at least twice with clean, warm water. Allow time for drying before painting exposed surfaces. **CAUTION: Caustic soda will burn the skin,** so as a precaution the workers must use rubber gloves and safety goggles.

**Combined Fungicidal Treatments.**—Sometimes two or more fungicidal treatments can be applied with good results while still maintaining residues within legal tolerances. Dowicide A-hexamine treatment and diphenyl pads can be easily combined, as can two Dowicide A-hexamine treatments. This is very good for: long shipments, fruit going into cold storage, fruit which must wait between picking and packing, or fruit going into polyethylene bags.

**Fungicidal Waxes.**—Solvent-type waxes are available with Dowicide A alone or Dowicide A and diphenyl. Water emulsion-type waxes are available with Dowicide A incorporated into the wax formula. Both types of waxes when properly applied give decay control. They should not be used on fruit that has been previously treated with Dowicide A because of the danger of exceeding the established residue tolerance.

**Labeling Fungicide-Treated Citrus.**—Containers (boxes, cartons, bags) filled with fungicide-treated citrus **must be labeled** to comply with the Federal Food and Drug Administration requirements. A typical label might read:

"Sodium *o*-phenylphenate used as a fungicide."

## GRADES AND GRADING

**Maturity.**—According to the Florida Citrus Code of 1949, as amended, all citrus fruit that is marketed must be mature. To be mature, an orange must show 50 percent natural color break (Parson Brown variety requires a 25 percent color break), and contain more than 4½ gallons of juice per box. Additionally, the juice must contain not less than 9 percent total soluble solids, and must meet the sliding scale requirements for solids: acid ratio (see the Florida Citrus Code). The standards for grapefruit, tangerines, Temples, tangelos, and Murcotts are slightly different. Tests are run on 10 fruit samples from each size (five fruits for grapefruit). If the sample does not meet the requirements (Regulation 1, Florida Citrus Commission), the fruit is destroyed.

**Grades.**—The U. S. Department of Agriculture standards and grades are based on external size, appearance (blemishes, discolorations, scars), fruit shape, and type. The standards recognized are Fancy, U. S. No. 1 Bright, U. S. No. 1, U. S. No. 1 Bronze, U. S. No. 1 Golden, or U. S. No. 1 Russet; U. S. No. 2 Bright, U. S. No. 2, U. S. No. 2 Russet; and U. S. No. 3. A tree-run grade is recognized by Florida Citrus Commission regulations and is unclassified.

Graders hand-sort the fruit as it travels across a roller conveyer and place each grade on a separate belt (Fig. 15). Splits, rots, and injured fruit go to the cull bin. Blemished but otherwise sound fruit (eliminations) are sent to the processing plant. Graders usually wear cotton gloves to prevent fingernail injuries to the rind.

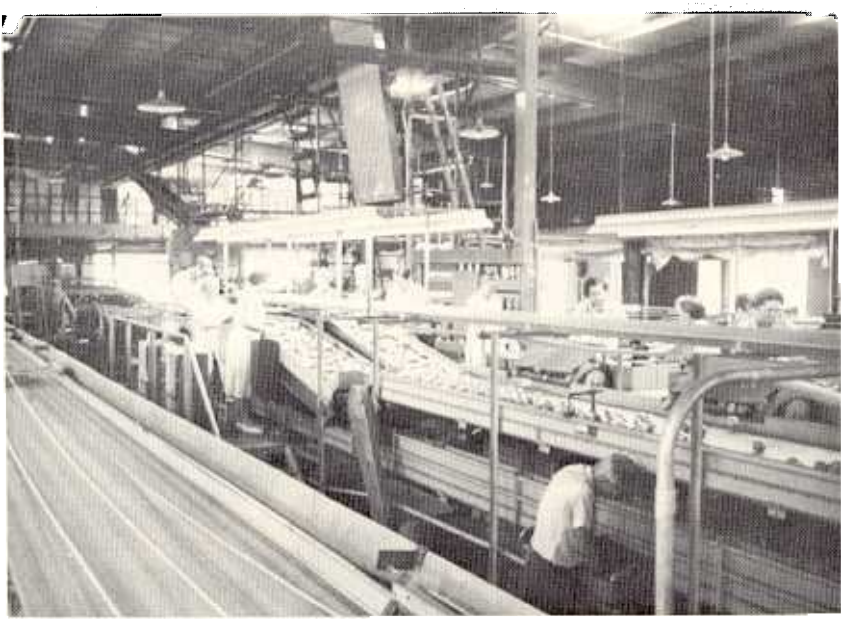


Fig. 15.—Grading citrus fruit at the grading tables.

**Sizing.**—After fruit has been graded, it is sized. Four types of sizers are in general use: (1) longitudinal belt and roll sizers with packing bins or roll-board tables, (2) central longitudinal belt and roll sizers, (3) transverse sizers, and (4) tangerine (tomato) perforated belt sizers.

The belt and roll sizer at the packing bin has been in use for many years. Size adjustment can be changed quickly from

grapefruit to oranges to tangerines. The machine is capable of fairly accurate sizing if properly adjusted.

The central sizers are of many types or variations, such as transverse roll and drop roll. The different sizes drop through onto canvas distribution belts and are transported to the packing stations.

The tangerine sizer consists of a belt or chain with certain size holes or meshes in each section. The main disadvantage is that each size requires a belt or chain, and to change sizes the belt must be changed. It works better for the flat type fruits than roller and belt sizers. It is used mostly for tangerines, tangelos, mandarins, and Murcotts.

If sizers are operated at high speeds, fruit may bounce, increasing injuries and decay. Also, the sizing is not as accurate in high-speed operation.

## PACKAGES AND PACKING

**Packing.**—Most of Florida's citrus fruits are place-packed by hand from bins or roll-board packing stations (Fig. 16 and Fig. 17). The older packinghouses use bins for each size. Each bin

Fig. 16.—Workers hand-packing oranges off a roll-board. Note empty box conveyer, box stands, and packed box conveyer. Rubber floor mat lessens fatigue, but the roll-board is too high for these three ladies, which increases fatigue. This could be corrected by building height racks for them to stand on.

is capable of storing several boxes of fruit. The packers pack from the side rather than facing the bin as they do with the roll-board stations. The roll-board is more efficient and less tiresome to packers, but fruit is only one layer deep. Therefore, little fruit can be stored and, unless there are enough packers, fruit can pile up and spill over on the floor. Some houses have deepened the roll-board to avoid this disadvantage, but this lessens the efficiency of packing. Ultimately, some baffle system will probably be devised for fruit storage. The under-the-bin packed box conveyers will be kept because of their efficiency.

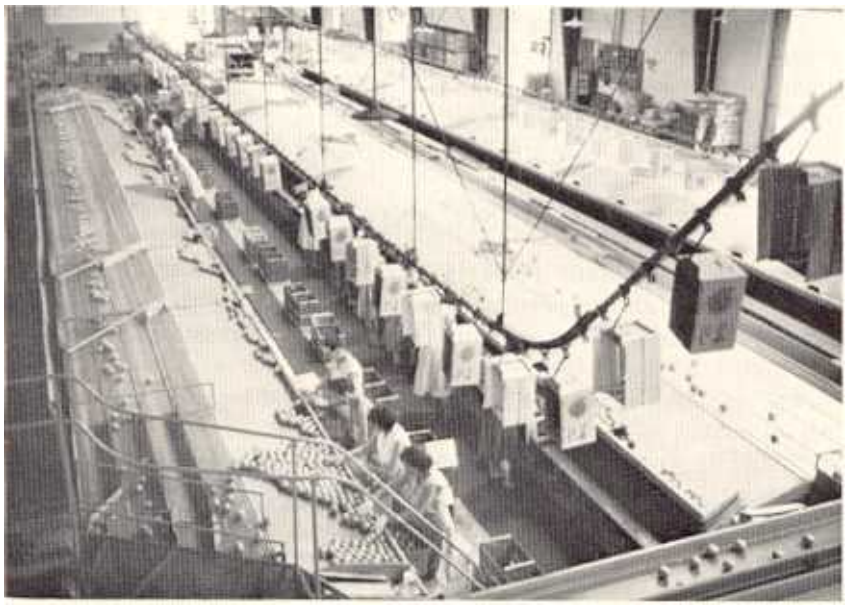


Fig. 17.—The packing area of a large house, showing three roll-boards and the empty box conveyer. Note fiberboard cartons and wirebound boxes on the empty box conveyer.

Some machine-packing is done using count or weight. Polyethylene film or mesh bags, 5- or 8-pound sizes, are the containers most used in machine packing, although some fruit is packed in 4/5-bushel corrugated containers. The reason for the small number of cartons or boxes being machine-packed is that each container usually requires a different filling machine just as each requires different closing machines. The fillers for bags can handle most of the sizes used. Probably more machine-filling would be done in Florida if labor costs were higher or fewer types and sizes of containers were used.

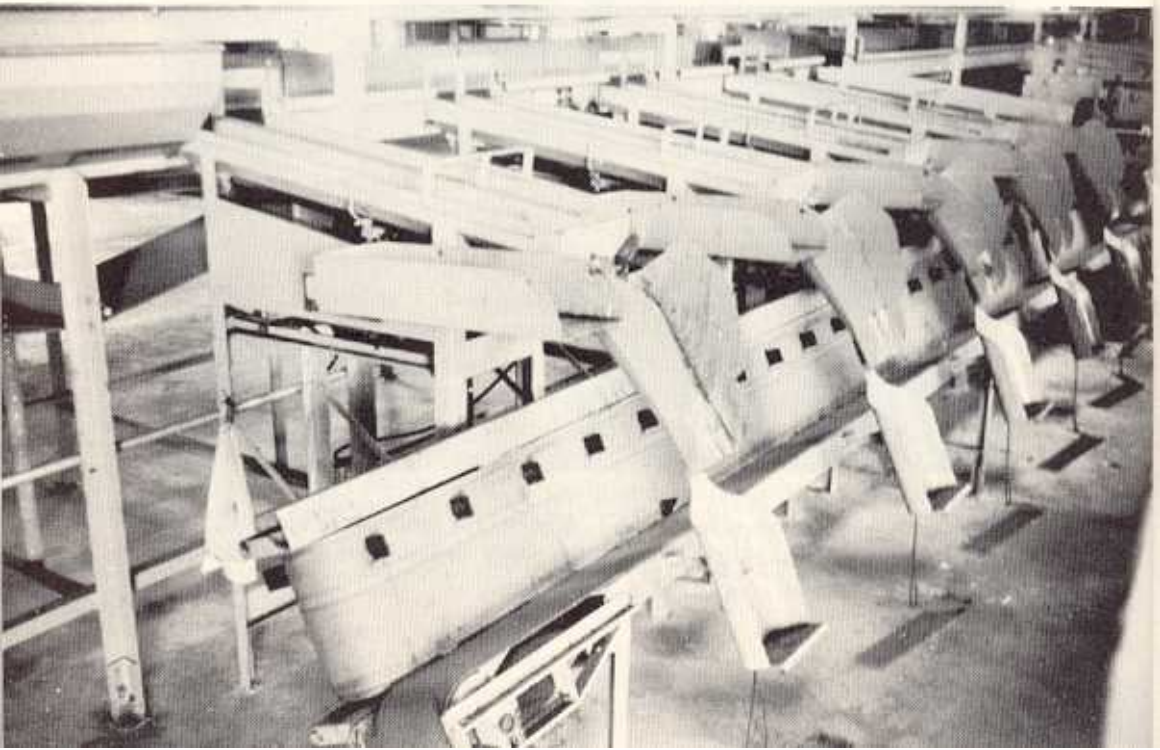
**Containers.**—Most Florida citrus is packed in 4/5- or 1 3/5-bushel wirebound boxes or in 4/5-bushel corrugated containers. Most of the remaining fruit goes into 5- or 8-pound poly or mesh bags (Fig. 18). These are shipped with or without master containers (wirebound or paper). However, several different types of consumer packages appear each year—tray packs, vue packs, cello-packs, tubes, plastic mesh bags, shrink packs, etc. Each consumer package requires a packaging station, special operations, a master container, and a distribution line to and away from the machine. This adds greatly to the distribution problems.

Container standardization on two or three types of containers or less would help solve these problems, increase the efficiency of house operation, and reduce the overhead and operating costs. Standardization will come slowly, because managers are quite willing to use any container the customer prefers.

## PRECOOLING AND STORAGE

**Precooling.**—Citrus fruit is often delivered from the grove at relatively high temperatures, especially during the hot weather early and late in the season. Packinghouse processes such as

Fig. 18.—One type of bagging equipment used for placing fruit in polyethylene film bags.



degreening, color-adding, and drying contribute further heat to the fruit. In addition, the natural heat of respiration may cause an appreciable increase in the temperature of large masses of packed fruit.

The value of refrigeration in extending the shelf life of citrus fruits has long been recognized. Shipment to market in railroad cars or trucks which are cooled with ice or mechanical refrigeration is common practice. Cooling of full loads of warm fruit under these conditions is slow and inefficient, so some method of precooling is desirable.

Special stacking patterns for cars and trucks that permit better circulation of air around the fruit improve the cooling rate for wirebound crates and ventilated cartons. Portable units having high refrigeration capacity and air flow are sometimes attached at the door of the loaded vehicle for several hours to precool the load of fruit before shipment. Some packinghouses place packed fruit in refrigerated rooms overnight before loading, but this type of cooling is inefficient, and rooms with sufficient capacity for a day's pack are too expensive to be practical for large operations.

It is possible to cool citrus fruits before packing with either cold air or water. Low heat capacity and poor heat transfer require exposure to large volumes of air to cool citrus fruits. Most packinghouses do not have enough room for sufficient line length to fully cool the fruit with air; this method is better adapted to a batch process using bins or pallet boxes in cooling towers or tunnels. Fruit which has been treated with Dowicide A-hexamine followed by air precooling shows outstanding keeping qualities, even when stored later at higher temperatures.

The high heat capacity of water combined with more rapid heat transfer makes hydrocooling of citrus fruit possible as a continuous process in the packinghouse line. Several Florida packinghouses are using this method commercially. Equipment consists of a trough through which the fruit is conveyed while a pump circulates large volumes of chilled water (33 to 35° F) around the fruit. Time required for cooling is normally 20 to 30 minutes.

Work at the Citrus Experiment Station showed that fruit which had been hydrocooled and later stored at 70° F frequently had higher decay than non-precooled fruit. Use of 0.1 percent Dowicide A in the cooling water at a pH of 10.5 and storage under continuous refrigeration at 50° F improved the keeping quality of hydrocooled fruit. Further experiments showed that

decay was directly proportional to time of exposure and temperature of the water rather than due to the shock of rapid cooling. Indications are that hydrocooling makes the fruit very turgid and more easily injured in subsequent handling, resulting in more decay by mold.

Hydrocooling can be quite useful for oranges which are to be packed in cartons or in polyethylene bags in master cartons. For best results, Dowicide A should be used in the cooling water, and packed fruit should be kept under refrigeration until consumed. This process is not as useful for grapefruit, since they cool more slowly due to the insulating effect of the thick peel and large size. With tangerines, water damage is often greater than any benefits provided by hydrocooling.

**Storage.**—Fruit in the early stages of maturity is usually best stored on the tree. Fruit of advanced maturity usually does not store well for long periods of time.

The best relative humidity for all citrus fruits is about 90 percent. Lower humidities favor rind breakdown and shriveling, and higher humidities favor mold growth.

Grapefruit storage temperatures depend upon the time the fruit is harvested, mainly because certain decay fungi are more common at certain times of the season. The best temperature is usually a compromise between that for decay control and that which will avoid pitting—a storage temperature that will give the least total economic loss. Diplodia stem-end rot is more common in the fall and summer, and temperatures of 50 to 55° F limit its growth. Green mold growth is also slowed at 50° F. However, if fruit has been handled roughly while being harvested, decay will be high, and 32 to 34° F will be a better storage temperature. In the winter and spring, Phomopsis stem-end rot is more common, and 32 to 34° F storage is necessary if decay is high. At 32 to 34° F, some pits develop, but they are smaller and not brown in color like those which occur at 40° F. If pitting is bad, 50 to 60° F is the best temperature. Pitting is more common on early grapefruit generally. They can be stored for 4 to 6 weeks.

Oranges are not troubled much with low temperature rind pitting, so the best storage temperature is 32° F. They can be stored for 4 to 8 weeks without too much spoilage.

Limes are best stored at 48 to 50° F and may be held up to 6 weeks. Lower temperatures, however, induce pitting and stylar end breakdown.

Lemons, when picked dark green in color, can be stored for long periods of time at 55 to 58° F (1 to 4 months). Terminal markets generally use 50 to 55° F.

Tangerines cannot be stored for long periods of time because of the nature of the fruit. The temperatures recommended are 31 to 38° F. Tangerines do not hold over 4 weeks at the most.

Long storage at low temperature may result in watery breakdown, stylar end breakdown, brown staining, pitting, and other physiological disorders. Freezing of the fruit usually occurs at about 28.5 to 29° F. Damage is most likely to occur at the bottom of the stacks or near the cold air entrance. If circulation is too rapid, increased shrinkage (weight loss) may occur.

The use of Dowicide A-hexamine solution and diphenyl pads greatly reduces decay losses in refrigerated storage. The storage life is also extended considerably. For example, oranges can be kept 3 or 4 months with slight decay loss at 30 to 34° F. Grapefruit can be kept 2 or 3 months with some loss. Decay of lemons, tangerines, and other citrus fruit is greatly reduced by fungicides and good refrigeration.

Fruit intended for long storage should be picked in the middle of the season for that variety, handled carefully to minimize wounding, processed promptly and carefully (treated with fungicides and wax), and stored at the lowest advisable temperature. In general, the lower the temperature, the longer fruit can be stored with less shrinkage and less decay.

## HOW PACKING AFFECTS THE FRUIT

Fruit are living organisms while on the tree and continue to live after harvest, taking up oxygen and giving off carbon dioxide, water, and heat. This process is known as respiration, and a measure of these rates is an indication of the living rate.

In an ideal situation, any handling practices that increase the respiration rate should be avoided. High temperature and rough handling of fruit increase the rate of respiration and may affect the external appearance. The external appearance of citrus fruit is important in consumer appear, as is internal quality and storage life. If the appearance is not satisfactory, the fruit will simply not be sold.

Considerable progress can be made in marketing higher quality fruit if the handling practices proved by experimental work and common sense are followed. Some of the common bad handling practices are listed and should be guarded against. Re-

search results justify these recommendations; however, no data are presented here in the interest of brevity. This is not a complete list and is given here as a guide.

I. Bruising Fruit

A. Dropping fruit more than 12 inches causes an increase in the respiration rate and a shorter shelf life of the fruit.

1. The picking and loading operation appears to be the biggest offender.
2. Unloading at the packinghouse and the packinghouse belt should be checked for rough handling. Dropping upon other fruit or padding is preferred to a hard surface, but the drop should be reduced to a minimum.

B. Loading fruit to excessive depths causes pressure bruises.

1. Unsprung field trailers and excessive speed on rough roads increase pressure bruises.
2. Overfilled field boxes often result in injury and pressure bruises when the filled boxes are set on top of one another when being loaded.

II. Peel Abrasions and Punctures

A. Boxes in poor condition, having sharp edges, splinters, broken straps, etc., should be repaired.

1. Sand in the bottom of boxes adds to peel abrasions.
2. Sharp corners in the packing line can be seen in many houses and should be eliminated.
3. Fruit should not be allowed to remain on the brushes too long at the beginning or end of a fruit lot or for any other reason.

III. Fruit should not be exposed to direct sunlight or to high temperatures in the field after harvest or while standing at the packinghouse.

A. Increased temperature raises the rate of respiration (18° F increase in temperature doubles the rate). The heat of respiration adds to the temperature of fruit. This can be serious when fruit loads remain standing in the field or on the packinghouse floor for long periods.

B. Excessive sunlight may burn or bleach the fruit surface and increase the fruit temperature.

IV. The fruit is firmer under humid conditions and more easily injured. Picking during the early morning hours or after rains while the fruit is still wet should be avoided. Picking fruit that is dry reduces peel injury and decreases humidity in the container, thus reducing the probability of decay.

V. Build-up of carbon dioxide should be avoided.

A. When fruit is stored in a closed container such as the degreening room or an unvented polyethylene bag or box liner, there is a possibility of build-up of carbon dioxide to greater than 1 percent. This build-up depends upon temperature, as previously mentioned. Concentrations above 1 percent can result in off-flavors, and may stop degreening action in degreening rooms.

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