Abstract. Postharvest wt loss of most of the major citrus cultivars (cvs.) grown in Florida was determined at 4 different combinations of humidity and temp. Weight loss comparisons were made monthly with Indian River-grown seedless grapefruit. Similar comparisons were made with other cvs. during their respective maturation seasons. Weight loss was approx halved in fruit held either at 40 or 70°F with 90% relative humidity (RH) rather than ambient humidity. Humidity was maintained at 90% with humidistat-controlled pneumatic water-atomizing nozzles. Weight loss within each holding condition for each type of fruit showed limited variation.

Weight losses of Florida citrus fruit are closely related to the environment in which the fruit are held after picking, whether in the grove, packinghouse, or in storage. Citrus fruit degreened at about 96% RH had an average wt loss of less than 0.75% (1). Shrinkage and wt loss during degreening were found to be less than 0.05 inch in diam and 2.9%, respectively, after 84 hr degreening time at 85°F with humidity maintained at 85% or higher (5). Lowering the RH of California lemon storage by 5% without changing the temp was found to more than double the shrinkage rate (3). In Florida, degreening oranges without adequate humidity control resulted in a marked decrease in larger sizes with a corresponding increase in smaller sizes due to dehydration (4).

This study compared wt loss of waxed citrus fruit held under 4 storage environments which could be related to conditions in packinghouses, or during shipment and marketing. Commercial methods are suggested for reducing this wt loss.

Materials and Methods

Weight loss comparisons were made with most citrus cvs. commonly grown in Florida when held under the following storage conditions: (1) 70°F (21°C) with 90% RH, (2) 70°F with ambient humidity, (3) 40°F (4.5°C) with 90% RH, and (4) 40°F with ambient humidity. Relative humidity was maintained at approx 90% with humidistat-controlled pneumatic water atomizing nozzles. Ambient humidity at 70°F averaged 65% RH, ranging from 37 to 81%; while at 40°F, the average ambient humidity was 75% RH ranging from 64 to 82%.

Starting in November 1974, wt loss comparisons were made monthly through May 1975 with Indian River-grown seedless grapefruit. 'Ruby Red' grapefruit were used in the first experiment and 'Marsh' grapefruit for the remainder of this series. Commercially packed, size 40 grapefruit from one packinghouse were used for all monthly comparisons. In the March experiment, size 27 'Marsh' grapefruit were included to compare wt loss of the larger sized fruit with size 40. The fungicidal treatment was 600 ppm Benlate (benomyl) applied as a nonrecovery spray followed with a water-based wax.

'Hamlin,' 'Pineapple,' and 'Valencia' oranges; 'Dancy' and 'Murcott Honey' tangerines; and 'Temples' from the groves of the Agricultural Research and Education Center at Lake Alfred were used for other wt loss comparisons. These fruit were treated with a 600 ppm Benlate non-recovery aqueous spray to minimize decay during storage. A solvent-type wax was applied after the fungicidal treatment.

Sound fruit of good quality were selected for wt loss comparisons. Fourteen or 15 individually numbered fruit were used for each storage condition. Individual fruit were numbered with a felt-tip pen and weighed at the start of each experiment, then placed in mesh bags. Fruit were then weighed at weekly intervals for 4 weeks, except for 'Dancy' tangerines which had so much decay in the fruit held at 70°F that the experiments were discontinued after 3 weeks storage. In one experiment, packed 'Valencia' oranges were numbered, weighed, and bagged as described, then the bagged fruit were replaced in the cartons from which they were taken. Fruit handled in this way were placed under the 4 storage conditions to compare wt loss with bagged fruit which were not stored in cartons.
Only fruit which remained sound during the storage period were used to obtain average wt loss figures.

**Results and Discussion**

Percentage wt losses were found to be quite uniform for each storage condition for seedless grapefruit, round oranges, and mandarin-type citrus fruits. Weight losses of size 40 seedless grapefruit were increased by storing at ambient rather than high humidity at the same temp, and by storing at 70°F compared with 40°F (Fig. 1). Percentage wt losses of size 27 grapefruit were similar to that of size 40 fruit, indicating that size is not an important factor in wt loss.

Weight losses that can be expected in 2,000 lb. (1 ton or ca. 45-48 cartons) of seedless grapefruit or round oranges at 4 different storage conditions are shown in Fig. 2. The higher wt losses in oranges and mandarin-type citrus fruit are probably more related to the nature of the fruit than to the larger surface:mass ratio. Mandarin-type citrus wt loss was a little higher than round oranges at 70°F, but slightly lower at 40°F storage temp.

![Fig. 1. Comparison of wt losses of size 40 seedless grapefruit held in mesh bags at either high (90% RH) or ambient humidity. Storage temp were 40 and 70°F at both humidity levels. Vertical bars represent the standard deviation.](image)

Round oranges and mandarin-type citrus fruits stored at 40°F had good to excellent appearance after 4 weeks storage (3 weeks for 'Dancy' tangarines), whether held at high or ambient humidity. Peel injury typical of chilling injury which developed in some lots of grapefruit stored at 40°F was not severe enough to require discarding fruit. When peel injury did not develop, the appearance of the grapefruit was excellent. Fruit stored at 70°F with ambient humidity became soft and developed peel injury associated with dehydration. Fruit stored at 70°F with high humidity were firmer with little peel injury and in most instances were of marketable quality throughout the storage period.

Storing oranges at 70°F in cartons vs. mesh bags reduced wt loss by about 55% for fruit held at ambient humidity and 33% for fruit stored at 90% RH. The percentage wt loss was not changed when fruit in cartons were compared with bagged fruit at 40°F holding temp, regardless of humidity.

The rate of water loss is influenced by the relative pressure exerted by water vapor within and outside of the fruit (vapor pressure differential) and the effect is greatly magnified by increasing temp (2). Maintaining citrus fruit in a humid environment is an important factor in reducing the rate of water loss. Weight loss can be minimized by reducing the time citrus fruits are exposed to low RH, especially when the ambient temp is high.

There were differences in wt losses for each cv. at each storage condition and between the 2 years covered by this experimental work. These differences were due to variation in ambient con-
CONDITIONS DURING STORAGE AND SEASONAL VARIATIONS

CONTROLLING HUMIDITY IN STORAGE MATERIALLY REDUCED WT LOSS.

LITERATURE CITED


EFFECTS OF PRESTORAGE CARBON DIOXIDE TREATMENTS AND DELAYED STORAGE ON CHILLING INJURY OF 'MARSH' GRAPEFRUIT

T. T. Hatton and R. H. Cubbedge

Agricultural Research Service, USDA Orlando

AND

W. Grierson

Agricultural Research and Education Center University of Florida

Lake Alfred

Abstract. Prestorage treatments of 10, 20, and 40% carbon dioxide (CO2) for 3 and 7 days at 70°F (21.1°C) significantly reduced rind pitting, a type of chilling injury (CI), in grapefruit (Citrus paradisi Macf.) stored at 40°F (4.4°C) for 8 and 12 weeks. Prestorage at 70°F in air for 3 and 7 days was as effective as prestorage CO2 in reducing CI. Fruit stored continuously at 40°F in air had excessive CI. Treatments resulted in no significant differences in decay, and the fruit were palatable.

A separate test showed that holding late grapefruit in 25% CO2 or higher concn for 2 to 3 days prior to storage at 40°F induced resistance to CI for 55 days with no adverse effects on decay or flavor during or after storage.

CI is a physiological disorder usually located on the stem end or on the periphery of the fruit. The spots are sunken, relatively small and, at first, are not discolored. Later they become pink or tan and eventually brown.

CI has been recognized as a limiting factor in long-term storage (1) and export (4) of Florida grapefruit. Exposure of grapefruit to atm containing 20 to 45% CO2 for 20 to 48 hr prior to low-temp storage decreased later development of CI without effect on flavor (1). Modified atm within packaging films extended the shelf life of grapefruit (15); however, previous studies with less permeable films showed that such atm often caused extensive decay, damage to the rind and flesh texture, and off-flavors (8,12). More recent studies with polyvinyl chloride (PVC) film indicated that atm high in CO2 (up to 20%) almost eliminated CI in early and midseason pickings, but accentuated it in the late (post-bloom) picking (14). These studies also showed that modified atm tended to increase decay regardless of picking date. CI was reduced in Texas red grapefruit stored in a modified atm of 10 to 15% CO2 for 4 weeks at 40°F (11). A concn of 10% CO2 in controlled-atm (CA) storage at 40°F reduced CI of 'Marsh' grapefruit, the effect persisting for 3 weeks after removal of the fruit to air storage at 40°F (13).

The primary purpose of our studies was to determine the effects of CO2 concn and exposure times on development of CI in grapefruit stored at 40°F. Previous studies by the USDA Orlando laboratory indicated that mid-season 'Marsh' grapefruit exposed to 20% CO2 for 14 days, then stored for 8 and 12 weeks at 40°F, developed negligible CI (10), but that late-season grapefruit treated similarly responded less satisfactorily. This late-season effect was confirmed in subsequent experiments (9).

MATERIALS AND METHODS

Test 1. 'Marsh' grapefruit were harvested from 3 commercial groves in Indian River County,