3. Kimball, D. A. 1984b. Brix/acid ratio correlation with climatic data for California Navel and Valencia oranges. The Citrus Ind. Mag. August, p. 26-28.
4. Newman, J. E., W. C. Cooper, W. Reuther, G. A. Cahoon, and A. Peynado. 1967. Orange fruit maturity and net heat accumulation, p. 127-147. In: R. H. Shaw (ed.). Ground level climatology. Amer. Assoc. Adv. Sci. Publ. No. 86.
5. Reuther, W. 1973. Climate and citrus behavior, p. 281-333. In: W. Reuther (ed.). The Citrus Industry, Vol. III. Univ. of Calif. Press, Berkeley, CA.
6. Ting, S. V. and R. L. Rouseff. 1986. Citrus fruits and their products. Marcel Dekker, Inc., New York, NY.
7. Tucker, D.P.H. and W. Reuther. 1967. Seasonal trends in composition of processed Valencia and navel oranges from major climatic zones of California and Arizona. Proc. Amer. Soc. Hort. Sci. 90:529-540.

Proc. Fla. State Hort. Soc. 103:255-258. 1990.

QUALITY CHANGES DURING HARVESTING AND HANDLING OF 'VALENCIA' ORANGES

JACQUELINE K. BURNS AND ED ECHEVERRIA
Citrus Research and Education Center
University of Florida, IFAS
700 Experiment Station Road
Lake Alfred, FL 33850

Additional index words. citrus, mechanical damage, acid, Brix, ethanol, storage.

Abstract. **External and internal quality of 'Valencia' oranges was monitored at 7 stages of the commercial harvesting and handling process. The greatest amount of external damage was found in fruit collected at the pallet bin and at pack inghouse departure. Mechanical damage incurred at harvest was largely removed during grading, but additional damage occurred in the packinghouse. No further external damage occurred after this point. Peel and pulp temperatures, monitored during transport from the packinghouse to the warehouse, decreased 1°F/hr over a 20 hr transportation period. Pulp temperatures were always greater than the peel during this time. Percent acid, measured in fruit initially collected after each marketing event and after 4 weeks storage at 50°F, 90% RH, declined significantly only in stored fruit late in the handling sequence. Brix of initially evaluated and stored fruit increased significantly after harvest and remained high during handling. Waxing with a solvent-based wax had no significant effect on % acid or °Brix. Juice ethanol increased in stored fruit collected at packinghouse departure and increased only slightly thereafter; whereas, a significant increase in non-stored fruit occurred only in fruit collected at simulated consumer storage.**

The Florida citrus industry produces a high quality fresh fruit crop for domestic and international markets. Fruit destined for fresh market are subject to a variety of handling events that can ultimately affect the external appearance and internal quality of the fruit. Hand harvesting of round oranges has often resulted in a variety of external damages, the highest percentage of which were plugged fruit (2, 8, 10). Although packinghouse grading removed any fruit with external defects, a high percentage of fruit which had plugging damage (stem-end tears) passed through the packinghouse unnoticed and were found in the final packed carton. No further increase in external damage was found during later handling events. Decay was not detected until the retail and consumer marketing channels (2).

Internal quality can also be affected by harvesting and handling events. Whereas external damage occurred primarily at harvest, internal quality of 'Hamlin' oranges was most affected during later handling events (2). A rapid and significant decline in % acid and °Brix was measured in stored fruit originally collected at packinghouse departure. Acid and Brix remained low but unchanged throughout the remainder of the marketing sequence. A sharp increase in % juice ethanol, an indicator of anaerobic metabolism (3), was also measured during the later portion of the marketing sequence. Although the data suggested that packinghouse treatment, such as wax application, resulted in change in internal quality (2), measurements were only performed on stored fruit and not on those initially brought from each marketing event. Thus, the effect of time of storage and handling event could not conclusively be separated.

A study was initiated in 1989 to provide additional data on the effects of harvesting and handling on external and internal quality of 'Valencia' oranges. Internal quality was assessed directly after fruit collection and after storage to clarify the effects of handling and storage. Seven sampling points were chosen along the commercial harvesting and handling sequence, and the effects of waxing on internal quality was also assessed.

Materials and Methods

Plant material. 'Valencia' oranges (*Citrus sinensis* Linn. Osbeck) were harvested in April from an established grove in central Florida. Fruit were hand harvested simultaneously by a commercial grove crew (commercial fruit) and by a selected crew from the Citrus Research and Education Center, Lake Alfred, FL (control fruit). Only fruit of size 125 (fruit/carton) were harvested. Fruit from 7 specific points along the commercial harvesting and handling sequence (Table 1) were evaluated. After each harvesting and handling point, commercial fruit were divided into 2 subsamples, each containing 2 cartons. One subsample was evaluated for external quality immediately and then internal quality determined as described below; the other was stored at 50°F, 90% RH for 4 weeks, and then analyzed. Control fruit were harvested directly into cartons and transported to the LA-CREC. Fruit were divided into 4 subsamples, each containing 2 cartons. Each subsample was washed and 1000 ppm TBZ applied. Two subsamples

Florida Agricultural Experiment Station Journal Series No. N-00344.

Table 1. Description of the sampled points along the harvesting and handling sequence of 'Valencia' orange.

No. days from harvest	Description	
–	*point 0:*	fruit were collected directly after hand harvest. Pickers were instructed to harvest directly into cardboard cartons.
–	*point 1:*	fruit were collected from pallet bins in the field.
1	*point 2:*	fruit were collected from pallet bins after transport to the packinghouse. Pallet bins were transported in late afternoon then stored at ambient temperature and RH until the following morning.
1	*point 3:*	fruit were collected at packinghouse departure. Additional cartons were randomly selected, bound together, and stored at 50°F until transport to the warehouse in Atlanta, GA. Transport began at 6:00 PM in an empty semi-truck. Three loads were picked up in the central Florida area before transportation to Atlanta began.
3	*point 4:*	fruit were collected after warehouse arrival. Fruit were stored at 40°F in the warehouse. Same-day transportation to the retailer.
10	*point 5:*	fruit were collected one week after retail arrival. Fruit were stored at 40°F, 90% RH.
17	*point 6:*	fruit were collected one week after simulated consumer storage: 75°F, 80% RH.

were waxed with solvent-based wax, the other 2 subsamples remained unwaxed. Waxed and unwaxed control fruit were further divided into fruit for immediate evaluation (non-stored) or fruit for storage under the same conditions as above. Fruit for immediate evaluation were stored as above and removed for analysis when commercial fruit from each handling point were evaluated.

Transportation from packinghouse to warehouse. Peel, pulp, and trailer temperatures were monitored at 15 min, 30 min, and then hourly intervals for the first 20 hr of transportation. In the center of the load of fruit, a single fruit was chosen in the middle of a carton and thermocouples inserted. The load from the packinghouse was placed in the rear of the trailer.

Fruit evaluation—external appearance. External damage was evaluated visually. Commercial and control fruit were evaluated at points 0, 1, 3, and 6. Handling damage was assessed and divided into bruised, scratched, stem-end torn (flavedo torn and albedo exposed), plugged (both flavedo and albedo torn), pitted, and decayed categories. Two cartons (250 fruit) were evaluated for each handling point. Percent fruit affected was based on the total fruit evaluated.

Fruit evaluation—internal quality. Juice was extracted from cartons of fruit with an FMC in-line extractor. Percent acid, °Brix, and ratio were determined by an FMC auto-analyzer (12). Juice was then collected and ethanol content was determined by gas chromatography as described by Davis and Chace (4).

Results

External damage. Fruit were closely scrutinized for external damage at all points of evaluation. At point 0, no bruised or plugged fruit were found in commercially harvested fruit. However, increased amounts of these damages were detected when fruit were collected from the pallet bins (Table 2). Percentages of stem-end torn, scratched, and pitted fruit also increased from point 0 to point 1. The amount of bruised and stem-end torn fruit detected in the cartons decreased when fruit were evaluated at packinghouse departure, whereas scratched and pitted fruit increased. Only small percentages of external damages were deteced in control fruit at point 0. Little change in external damage was observed in these fruit at packinghouse departure (Table 2) or through the later handling points (data not shown). In addition, external damage in commercial fruit did not change throughout the later handling points. Decayed fruit, absent in control and commercial cartons evaluated through packinghouse departure, rose to 5% in cartons evaluated after simulated retail storage (data not shown).

Table 2. Categories of fruit damage detected in harvested and handled 'Valencia' oranges.

	% Fruit evaluated					
	pt 0		pt 1		pt 3	
	comm[z]	con	comm	con	comm	con
Bruised	0	0	6	0	2	0
Plugged	0	0	1	0	1	0
SE tears[y]	5	3	11	3	7	3
Scratched	11	4	20	4	50	5
Pitted	3	2	15	2	60	2
Decayed	0	0	0	0	0	0

[z]comm = commercially harvested fruit; con = control fruit.
[y]SE tears = stem-end tears.

Transportation to the warehouse. Peel, pulp, and trailer temperatures were monitored during the 20 hr of transport from the packinghouse to the warehouse (Fig. 1). The refrigerated trailer was set at 39°F throughout the transportation period. There was a rapid decline in tempera-

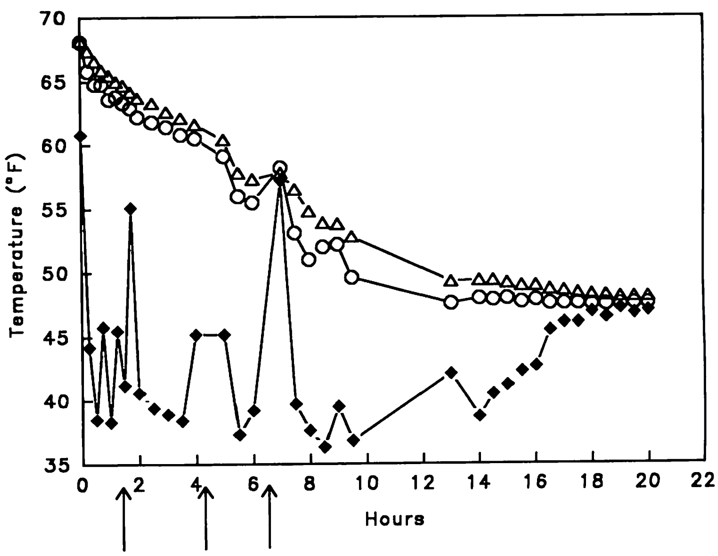

Fig. 1. Peel (O) and pulp (Δ) temperatures of 'Valencia' oranges during transport from the packinghouse to the warehouse in Atlanta, GA. Trailer (♦) temperature was also monitored. The values represent a single measurement. Arrows indicate times which additional fruit loads were added.

ture as transportation began. Some cycling of temperature around the set point was also observed. The addition of other fruit loads resulted in a brief rise in trailer temperature. During the latter portion of transportation (daylight hours), an increase in trailer temperature was measured. Average peel and pulp temperatures, initially at 68°F, slowly declined 20°F during 20 hr of transportation. Pulp temperatures were always higher than the peel, the difference ranging from 1.1 to 3.8°F. Only after 17 hr of transportation did the temperature difference drop below 1°F.

Internal quality changes. No significant changes in % acid occurred in control fruit from point 0 to point 6. A significant decline in acid was measured in stored control fruit only at point 6 (Fig. 2A). The use of solvent-based wax had no effect on the changes in % acid in stored or non-stored fruit (data not shown). The same trends in acid were observed in stored and non-stored commercially handled fruit.

Brix did not change in stored and non-stored control fruit throughout the harvesting and handling periods (Fig. 2B). A significant rise in Brix was measured in both stored and non-stored commercial fruit at point 2. During this time, % juice by weight in non-stored commercial fruit was 62.5 ± 0.5, 61.5 ± 0.6, and 61.3 ± 0.3 from point 0, point 1, and point 2, respectively. Similar changes were measured in stored fruit. After point 2, Brix levels declined significantly but remained above the levels measured at harvest. Waxing the fruit with a solvent-based wax had no significant effect on Brix levels in these fruit (data not shown).

In stored and non-stored control fruit, the Brix/acid ratio fluctuated during the harvesting and handling period (Fig. 2C). The ratio was significantly higher in stored control fruit at points 5 and 6 than any other handling point; whereas, in non-stored fruit, the net effect was no change in ratio. In commercially handled fruit, there was a trend of increasing ratio throughout the harvesting and handling sequence.

The level of ethanol in the juice was unchanged in stored and non-stored unwaxed control fruit throughout the handling period (Fig. 2D). There was a trend of increasing ethanol content in commercial fruit as well, but the increases were especially sharp and significant at points 3 through 6 in stored fruit and at points 5 and 6 in non-stored fruit.

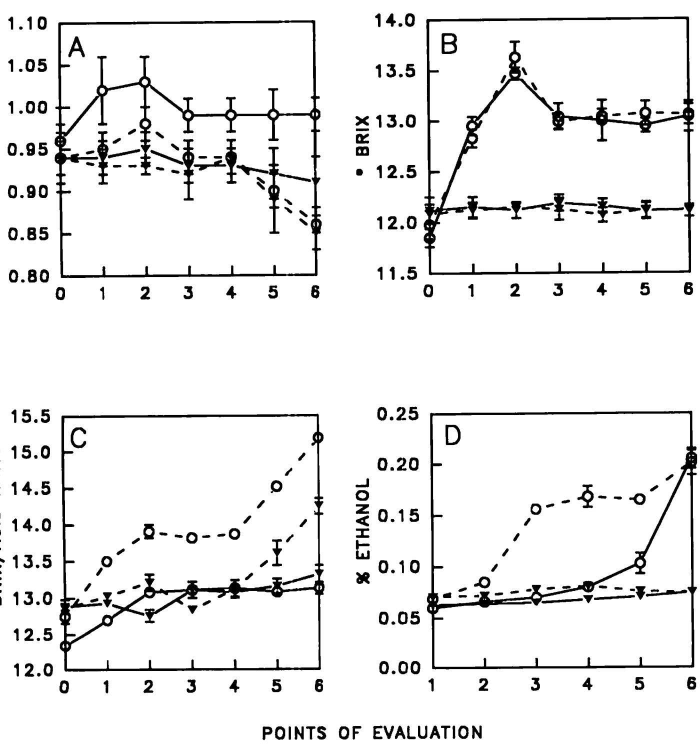

Fig. 2. Changes in % acid (A), °Brix (B), ratio (C), and % ethanol (D) during harvesting and handling of stored (---) and non-stored (—) 'Valencia' oranges. The data are the means ± sd. ○ = commercial fruit, ▼ = control fruit.

Discussion

Our previous findings with 'Hamlin' oranges had indicated that hand harvesting had the most detrimental effect on external appearance (2). With 'Valencia' fruit harvested by a commercial crew, close scrutinization of fruit from all handling points revealed that hand harvesting as well as packinghouse operations appeared to result in the most damage. The damage found at point 2 (at the pallet bin) probably reflected a more realistic estimate of fruit damage, especially of the stem-end tear type, since the commercial pickers were unaware of sampling in that area. An unusual amount of sand was noted in the pallet bins which likely resulted in a large amount of scratched- and pitted-type damage. Whereas the packinghouse grading process resulted in a decrease in bruised and stem-end torn fruit, the amount of scratched and pitted fruit actually increased at this point. This may have been a result of the high volume of fruit run through the packinghouse and/or the amount of sand or debris present in the fruit loads that we noted during the packinghouse procedure. Alternatively, removal of only bruised and stem-end torn fruit by the graders may have inflated the amount of scratched and pitted fruit that was seen at packinghouse departure. Packout percentage was not obtained from the commercial packinghouse.

Differences in acid content were observed between stored and non-stored fruit at each handling point. A drop in acid would be expected with increased storage time and temperatures (7). During the handling process, significant changes in % acids only occurred after fruit were collected at point 6 (simulated consumer storage) and stored for 4 weeks at 50°, greater than 6 weeks from harvest. A significant decline in acid was measured in 'Hamlin' oranges from harvest to consumer handling, but these fruit were stored 8 to 12 weeks from initial harvest (2). In a previous study with stored 'Valencia' oranges, significant declines in % acid occurred only after 6 weeks of storage at 5° or 15°C (7). It is therefore likely that the decline in acid measured in stored 'Hamlin' oranges (2) was largely a response to storage time rather than handling. Refrigeration during handling may also have contributed to the reduction of acid in 'Valencia'. The benefits of low temperature storage and transit, such as decay reduction and weight loss control, have long been recognized (9).

Although unchanged in stored and non-stored control fruit, a sharp and significant increase in °Brix was measured in commercial fruit collected at the pallet bin and after transport to the packinghouse. During this time, % juice in commercial fruit decreased 1.9 and 2.7% in stored and non-stored fruit, respectively, much less than would be required to raise Brix to the observed levels due to moisture loss alone. The elevated Brix levels appeared to persist throughout the remainder of the handling period. The increase in soluble solids may not necessarily reflect an increase in sucrose, glucose, and fructose, but rather may result in release of soluble components from insoluble material in the fruit (5, 6). The breakdown of the insoluble material may have occurred as a consequence of elevated field temperatures (recorded at 84°F) which could increase the activity of enzymes present in 'Valencia' known to act on the insoluble components (1). Temperatures could have been even higher in fruit deep within the pallet bin, but this was not measured.

Ethanol accumulation, known to be an indicator of anaerobic metabolism and off-flavor development (3), was unchanged in unwaxed control fruit. In stored commercial fruit, ethanol accumulated after packinghouse departure and remained high throughout the handling sequence as previously reported (2). The increase in ethanol was not measured in initially-evaluated fruit until simulated consumer storage. Ethanol content has been shown to be affected by storage time and temperature and wax applications (3).

Wax applications had no significant effect on % acid or Brix levels in this study. In 'Valencia', single or multiple applications of wax had no effect on respiration rate (11), therefore, amounts of acids and Brix would be unaffected. Thus, the decrease in acid and Brix measured previously in 'Hamlin' oranges (2) at packinghouse departure was likely unrelated to wax application. However, the respiratory behavior of citrus fruit apparently varies between cultivars. For example, a single wax application significantly increased the respiratory rate of 'Dancy' tangerines (11).

Careful handling of fruit resulted in less external damage. This was evident based on damage found on control fruit as compared to commercial fruit. Instructed to harvest fruit directly into cardboard containers, commercial pickers were keenly aware of our damage assessment directly at harvest. The increased damage found on commercial fruit sampled at the pallet bin as compared to those sampled directly after harvest underscores the importance of careful fruit handling. The presence of excessive trash and sand during packinghouse handling was likely a cause of increased damage found at packinghouse departure, although other factors such as graders preference of eliminations, may have been involved.

The drop in % acid measured in stored fruit, with no decline in Brix, indicates that acids are preferred as respiratory substrate, especially during lengthy storage periods. An unbalanced and insipid fruit may result, and together with the increase in ethanol and potential development of off-flavors, suggests that fruit handled as in this study should not be marketed after 4 to 6 weeks after harvest.

Conclusions

In summary, internal and external quality changes of commercially harvested and handled 'Valencia' oranges were evaluated. The greatest external damage was detected during the first portions of the handling sequence and was manifested as scratched, pitted, and stem-end torn fruit. Acids were unaffected by handling, except in stored fruit late in the handling sequence. Brix increased early in the handling sequence, and ethanol accumulated in stored fruit at packinghouse departure and in non-stored fruit later in the handling sequence. We realize that this study represents a single harvesting and handling event and may not necessarily represent true trends in the marketplace. We will continue to evaluate additional citrus cultivars under similar handling conditions.

Literature Cited

1. Burns, J. K. 1990. α- and β-galactosidase activities in juice vesicles of stored 'Valencia' oranges. Phytochemistry 29:2425-2429.
2. Burns, J. K. and E. Echeverria. 1988. Assessment of quality loss during commercial harvesting and postharvest handling of 'Hamlin' oranges. Proc. Fla. State Hort. Soc. 101:76-79.
3. Davis, P. L. 1970. Relation of ethanol content of citrus fruits to maturity and to storage conditions. Proc. Fla. State Hort. Soc. 83:294-298.
4. Davis, P. L. and W. G. Chace. 1969. Determination of alcohol in citrus juice by gas chromatographic analysis of headspace. HortScience 4:117-119.
5. Echeverria, E. and M. Ismail. 1990. Sugars unrelated to Brix changes in stored citrus fruit. HortScience 25:710.
6. Echeverria, E., J. K. Burns, and L. Wicker. 1988. Effect of cell wall hydrolysis on brix in citrus. Proc. Fla. State Hort. Soc. 101:150-154.
7. El-Zeftawi, B. M. 1976. Cool storage to improve quality of 'Valencia' oranges. HortScience 51:411-418.
8. Grierson, W. 1968. Effect of mechanical harvesting on suitability of oranges and grapefruit for packinghouse and cannery use. Proc. Fla. State Hort. Soc. 81:53-61.
9. Grierson, W. E. and F. W. Hayward. 1960. Precooling, packaging, and fungicides as factors affecting appearance and keeping quality of oranges in simulated transit experiments. Proc. Amer. Soc. Hort. Sci. 76:229-239.
10. Rackham, R. L. and W. Grierson. 1971. Effect of mechanical harvesting on keeping quality of Florida citrus fruit for the fresh market. HortScience 6:163-165.
11. Vines, H. M., W. Grierson, and G. J. Edwards. 1968. Respiration, internal atmosphere, and ethylene evolution of citrus fruit. Proc. Amer. Soc. Hort. Sci. 92:227-234.
12. Wardowski, W., J. Soule, W. Grierson, and G. Westbrook. 1979. Florida citrus quality tests. Fla. Coop. Ext. Serv. Bul. 188. 30 p.