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ASSESSMENT OF QUALITY LOSS DURING COMMERCIAL HARVESTING AND POSTHARVEST HANDLING OF 'HAMLIN' ORANGES

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Abstract. **'Hamlin' oranges were followed through commercial marketing channels from grove to consumer and quality loss was assessed. External physical injury occurred as a result of picking. Injury was expressed as stem end tears, torn buttons, bruising, scratching, and plugging. At packinghouse departure, the only external injury that remained was stem-end tears. No further external injury occurred as a result of handling through market channels. Decay was not initially detected until retail and consumer handling points (14 and 21 days after harvest, respectively), but increased significantly at all handling points after 4 and 8 weeks of storage at 60°F. Total loss due to decay was greatest at the retail handling point. To accentuate changes in internal quality indices that may result from postharvest treatment and handling, juice quality was evaluated after 8 weeks of storage in commercial fruit lots and compared to nonwaxed controls. Waxing resulted in a decline in acid and Brix and an increase in ethanol content. Further handling time resulted in smaller changes in all 3 quality indices. The results suggest that most external injury occurs at harvest, whereas waxing and time held during further commercial handling is detrimental to internal quality.**

Florida fresh citrus growers produce a high quality crop each year that is delivered to consumers statewide, nationwide, and worldwide. A successful delivery of the product projects a positive image for Florida citrus and often results in repeat business. A visit to the marketplace, however, reveals a general loss of quality in some cases. In the past, studies have been conducted to address the problems of harvesting and handling. Studies by Grierson and coworkers (5, 7, 8, 10) set guidelines and standards of quality based largely on simulated harvesting and handling conditions and/or specific market point evaluations. The purpose of this study was to assess quality loss at 6 specific marketing points along the commercial harvesting and handling sequence. The present work uses a systems approach (11, 12) to assess quality loss of 'Hamlin' oranges (*Citrus sinensis* Linn. Osbeck) under commercial harvesting and handling conditions.

Materials and Methods

Commercial procedure. 'Hamlin' oranges were harvested from commercial groves near Winter Haven, FL. Commercial pickers harvested fruit and placed them first into picking bags and then into bins. When the bins were full, the bins were placed on a tractor-trailer where they remained until the end of the picking day. At the end of the day, the bins were transported to the packinghouse and placed in degreening rooms. Fruit were degreened for 36 hr at 85°F (29°C) and 85% relative humidtiy (RH) with approximately 5 ppm ethylene. After degreening, fruit were run through a commercial packinghouse and placed in standard cartons. Cartons of fruit were stored over the weekend at 40°F (4°C) and 95% RH. Cartons were then transported at refrigerated temperature (approx. 50°F or 10°C) to a commercial warehouse in Miami, FL, and subsequently to a retail outlet. At retail, the fruit were stored at 34 to 36°F (0 to 2°C) for one week. After one week cartons were brought to the Citrus Research and Education Center, Lake Alfred, FL, and subjected to conditions of simulated consumer storage at 75°F (24°C) and 80 to 85% RH for one week.

Points of evaluation and quality assessment. Fruit were evaluated at 6 different points (pts 1 to 6) along the harvesting and handling sequence: after placement of fruit by pickers into commercial bins (pt 1), after transportation to

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the packinghouse (pt 2), directly after packing into cartons (pt 3), at warehouse arrival (pt 4), one week after retail (pt 5), and one week after consumer storage (pt 6). The time elapsed from harvest was one day for pts 1 and 2, 3 days for pt 3, 6 days for pt 4 (an additional 3 days at the packinghouse for storage and transport), 14 days for pt 5 (one additional day at the warehouse for transport to retail outlet), and 21 days for pt 6. A variety of fruit sizes were evaluated at pts 1 and 2, but afterward only size #64 fruit were evaluated. Fruit were randomly taken from the bin at pts 1 and 2 and placed in cartons. At packinghouse departure, cartons of fruit were assigned random numbers and sampled thereafter in numerical order. Four cartons of fruit were evaluated at each marketing point. A total of 330 and 319 fruit were assessed at pts 1 and 2, respectively, whereas 256 fruit were assessed at each point thereafter. At each point, fruit were initially inspected for external physical damage and decay and then stored at 60°F (15° C) for 8 weeks. This storage period was chosen because we felt that changes in internal quality would most likely be expressed after 8 weeks. In addition, 60°F was chosen because we felt it represented an average temperature in which fruit would be exposed during handling. An intermediate inspection of 4 weeks was included to remove decayed fruit and hence possible inoculum for the remaining healthy fruit. After each storage period, fruit were externally inspected for the presence of decay. Decayed fruit were discarded, and the remaining fruit were either returned to storage to fulfill the 8 week storage period, or were juiced and internal quality was determined. Juice was extracted from the cartons of fruit with an FMC in-line extractor. Per cent acid, °Brix, and ratio were automatically determined by the FMC auto-analyzer as described by Wardowski et al. (14). Juice was then collected and ethanol content was determined by gas chromatography (2). For comparison of internal qualities, fruit were carefully harvested from the same commercial groves, brought to the Research Center, washed, treated with 1000 ppm thiabendazole, not waxed, and stored under the same conditions. These control fruit were held the same total time as fruit sampled at each collection point but always at 60°F.

Results

Inspection of the external surface of the fruit immediately after commercial harvest revealed a substantial amount of physical injury. The external appearance of freshly harvested 'Hamlin' oranges were categorized as indicated in Table 1. Of the 1673 'Hamlin' fruit evaluated in this study, 17% were torn at the stem-end and were characterized by a torn flavedo at the stem-end which exposed albedo beneath. Ten per cent of the fruit had some portion of the button torn. Bruising, scratching, and plugging (flavedo and albedo torn, segment exposed) comprised 5, 2, and 1% of the total number of fruit, respectively. Similar external injury distributions were seen in 'Valencia' (4000 fruit assessed) although less injury expressed as stem-end tears was observed (data not shown). The amount of marketable fruit (fruit with no buttons, torn buttons, and sound fruit) of both varieties was also similar. External injury did not change from pt 1 to pt 2. Plugged, scratched, and bruised fruit were eliminated at the packinghouse, but the percentage of fruit which had stem-end tears was only 3% less in 'Hamlin.' Most of the remaining buttons on the fruit had abscised as a result of ethylene used in the degreening process (6). After final packing (pt 3), fruit external injury did not change.

Table 1. External appearance of 'Hamlin' oranges following commercial harvest.

Fruit category	% of fruit evaluated Hamlin
No buttons	40
Torn buttons	10
Plugged	1
Stem-end tears	17
Scratched	2
Bruised	5
Sound	25

At initial inspection, no fruit decay was detected until pts 5 and 6 (Fig. 1). More decay occurred at the intermediate handling points after 4 weeks of storage and was significantly less at pt 6. The per cent decay present after 8 weeks of storage was greatest at pts 2, 5, and 6. Per cent decay was significantly greater at pts 5 and 6 than pts 1 and 3. When per cent decay was pooled from all 3 inspections, a bimodal distribution of decay was found. Total decay was greatest at pts 2, 5, and 6 and was lower at pts 1, 3, and 4. No significant differences were detected in pts with higher percentages or lower percentages of decay; however, the amount of decay was significantly greater at pt 5 than pts 1, 3, and 4. The total decay loss of each inspection period was 2, 5, and 5% for initial, 4 week, and 8 week inspections, respectively. The 6% loss initially at pt 6 is what the consumer would have encountered. Little additional decay would have occurred if the fruit were held for

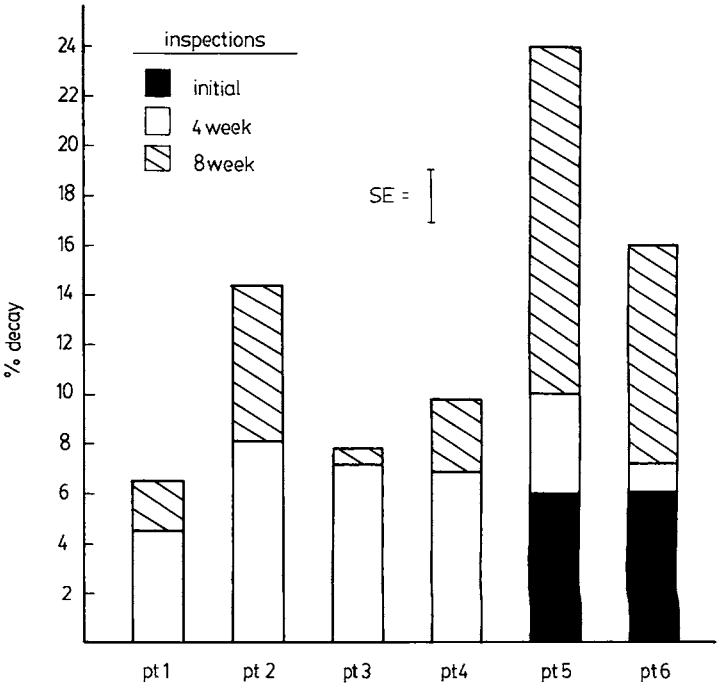

Fig. 1. Total decay (%) in 'Hamlin' oranges as affected by commercial postharvest handling. Handling points are: pt 1, after commercial harvest; pt 2, at packinghouse arrival; pt 3, at packinghouse departure; pt 4, at warehouse arrival; pt 5, one week after retail; and pt 6, one week after simulated consumer storage. Bar indicates standard error of the mean.

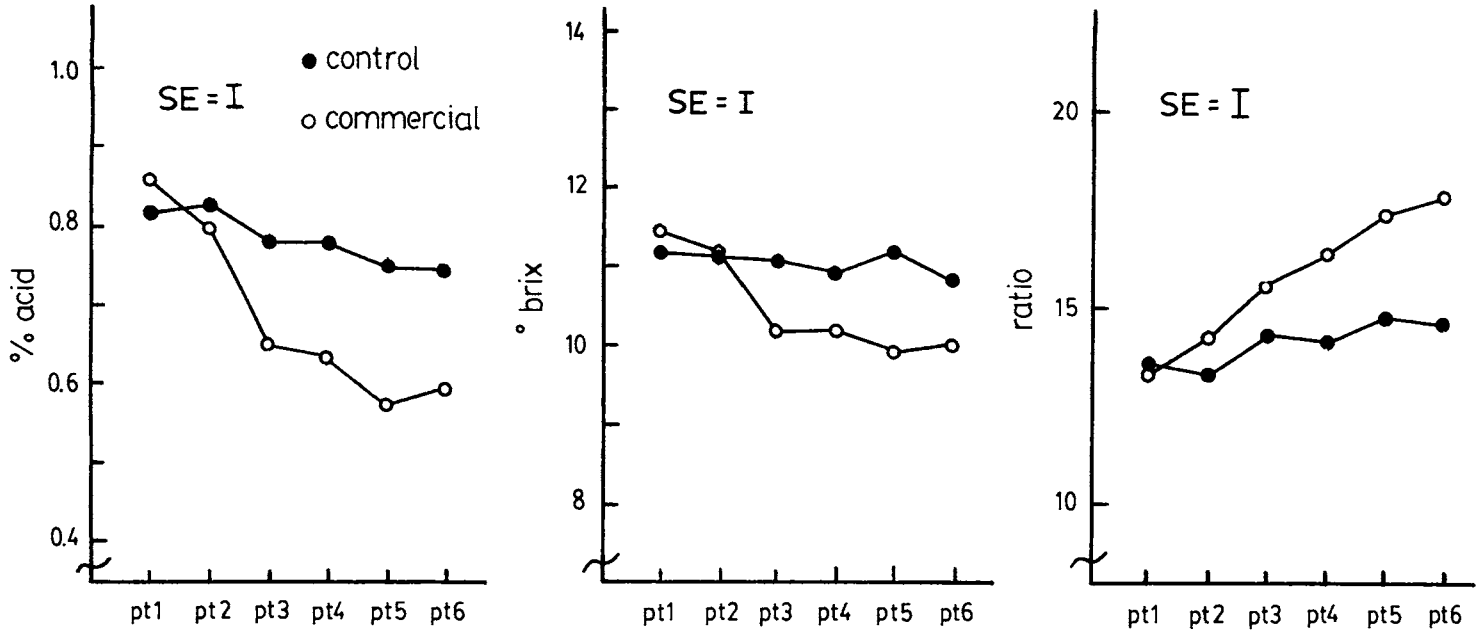

Fig. 2. Internal quality in 'Hamlin' oranges as affected by commercial postharvest handling. Description of handling points are as in Fig. 1. Bars indicate standard error of the mean.

an additional 4 weeks, but an additional 10% decay occurred over the next 4 weeks.

Internal quality was assessed in the 8-week stored fruit of commercial and control lots at each handling period. As commercially harvested fruit passed through the market channels, per cent acid declined more rapidly than °Brix which resulted in an increase in ratio (Fig. 2). A smaller decline in per cent acid occurred in control fruit and no significant changes occurred in °Brix. As a result, the ratio in control fruit increased only slightly over the handling sequences studied. The per cent ethanol present in the extractable juice of stored control fruit was low and did not significantly change from the original value at harvest (Fig. 3). A 10-fold increase in per cent ethanol was detected in commercial fruit from pt 1 to pt 4. Although ethanol levels continued to rise after pt 4, the increases were nonsignificant.

Discussion

The amount of marketable fruit in this study (the category sums of no buttons, torn buttons, and sound fruit) was 75% for 'Hamlin.' Packout would be less since windscarred and mite-injured fruit were not tabulated. Similar external injury distributions were obtained with Pineapple oranges hand harvested in Florida (10). Our study further divided plugging into an additional category of stem-end tears. Because 14% of the fruit evaluated after packinghouse departure still exhibited stem-end tears, a wound site and possible entry point was present for postharvest decay organisms after this market point. Torn buttons represent another wound site and entry point for decay organisms.

A relatively short period of time had elapsed between harvest and warehouse arrival, but 14 days had passed before the fruit were evaluated initially for decay at retail. This fact may explain the presence of fruit decay at the retail and consumer handling points. Another factor that must be considered is the conditions of storage and handling at the retail outlet. At retail, which was a specialty outlet, the fruit were stored in closed refrigerated chambers and with other commodities known to have high respiration and ethylene production rates. Decay was observed in some cases on the other commodities. Therefore, it is likely that the fruit may have been additionally stressed by retail storage conditions and predisposed to decay. Delayed handling at the packinghouse and warehouse may have also contributed to overall decay at retail (5).

Removal of decayed fruit initially at pts 5 and 6 most likely removed potential inoculum for healthy fruit and thus resulted in less decay at these handling points after 4 weeks of storage. After 8 weeks of storage, more decay occurred at pts 2, 5, and 6 than the other handling points.

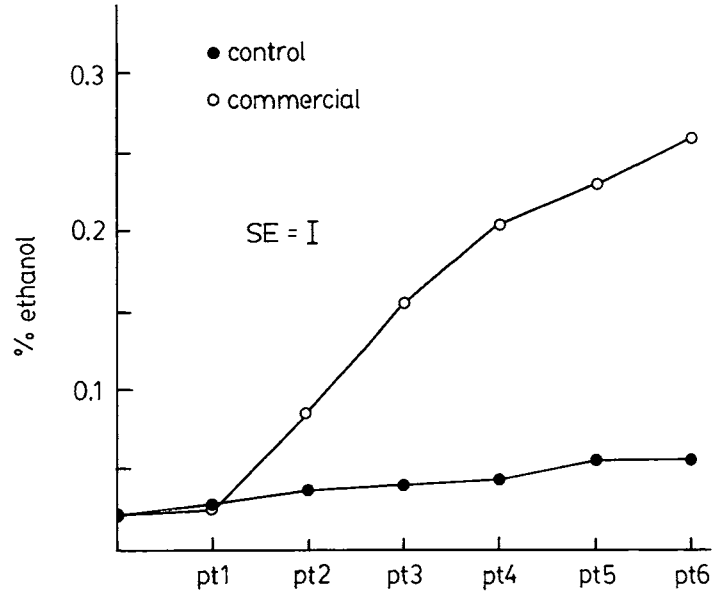

Fig. 3. Juice ethanol content (%) of 'Hamlin' oranges as affected by commercial postharvest handling. Description of handling points are as in Fig. 1. Bar indicate standard error of the mean.

The predominant types of decays found at these handling points were penicillium molds and to a lesser extent sour rot (data not shown). These decays are usually initiated as a result of injury during harvesting and handling (4). This is in contrast to the stem-end rot-type decays found initially and at the 4-week inspections. Thus, small surface injuries which may have escaped detection, such as injury that would result from sand abrasion in fruit transported in stacked bins to the packinghouse, or existing injuries (i.e., stem-end tears) which could be used as avenues of entry for decaying organisms in predisposed or stressed fruit at retail and consumer handling points, could have ultimately resulted in increased decay at these consumer handling points after 8 weeks of storage. Less decay may have occurred at packinghouse departure and warehouse arrival because injured fruit were removed during packing. Those fruit collected and stored after harvest (pts 1 and 2) were those which were not degreened, washed, waxed, had fungicide applied, or handled further. These fruit had the least amount of total decay after 8 weeks of storage. The pattern of the presence of decay after 4 and 8 weeks of storage indicates that, although significant amounts of decay occurred at the intermediate handling points, retail and consumer handling resulted in more total decay.

Internal fruit quality was assessed after 8 weeks of storage since we felt that additional storage time was needed to accentuate metabolic changes in quality indices as a result of handling. Initial juice quality was not determined. Whereas the external appearance of the 'Hamlins' was more affected at harvest, the data indicates that waxing and further handling was a detriment to the internal quality of the fruit. Transport to the packinghouse resulted in a decline in per cent acid, °Brix, and an increase in per cent ethanol, but the operations of the packinghouse resulted in significant changes in all 3 of the internal quality indices. The decline in acid and °Brix after packinghouse operations suggests that fruit waxing is detrimental to internal quality. Further handling resulted in only small declines in acid and Brix. Waxing changes the internal atmosphere of fruit (9) and may result in metabolic utilization of acids and soluble solids within the fruit. The internal quality changes after 8 weeks of storage may not accurately reflect the types or magnitudes of changes which occur during a normal marketing and sales time period. However, even though the fruit were stored for 8 weeks, we did not observe unusual values and trends in per cent acid, °Brix, ratio, and per cent ethanol content in control fruit or initially in commercial fruit. Accepting this, the data suggests that commercial handling of the fruit may have resulted in decreased internal quality. The fact that commercial samples from pts 1 and 2 and control samples contained a random assortment of large and small fruit and pt 3 contained only #64 fruit could have contributed to the observed decline in per cent acid and °Brix (13) at packinghouse departure. However, the decreasing trend of these quality parameters was observed at packinghouse arrival as well, which supports the proposed detrimental effect of commercial handling on internal quality. The steady increase in ethanol content with the commercially handled lot may also reflect the metabolism of degreened, waxed fruit (1, 3). Knowledge of the effects of waxing and further handling on internal fruit quality is important to the development of future methodologies of harvesting and handling.

In conclusion, we have evaluated quality of commercial 'Hamlin' oranges as the fruit are commercially handled from the grove to the consumer. Commercial harvesting resulted in significant external physical damage, whereas further handling resulted in loss of internal quality. In addition, decay losses were greatest at the retail outlet and most likely reflected the cumulative handling effects at all points. It must be emphasized that this study represents a single marketing event and may not accurately reflect trends in the marketplace. Efforts in the future will be directed towards the testing of additional citrus cultivars under similar marketing conditions.

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