

CONTROLLED ATMOSPHERE/HIGH TEMPERATURE FORCED AIR: A NON-CHEMICAL QUARANTINE TREATMENT FOR STONE FRUIT

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The major objectives for the fruit quality portion of this project were: 1) To complete sensory evaluation for five peach and nectarine varieties to determine if controlled atmosphere high temperature forced air treatment (CATTS) affects the appearance and taste of the fruit; 2) To determine if CATTS treatment could substitute for pre-ripening (conditioning) for the prevention of internal breakdown during storage; 3) To test previously untested varieties of peaches and nectarines to enlarge the number of varieties that have been surveyed for tolerance to CATTS treatment. 4) Determine if peaches and nectarines in industry boxes stacked onto pallets can tolerate CATTS treatment.

Entomological objectives included: 1) Submit report of completed confirmatory and efficacy tests for codling moth and oriental fruit moth to Dr. Ken Vick (USDA-ARS) and USDA-APHIS for proposal to Japan (MAFF) and Mexico; 2) Perform preliminary work to determine an efficacious CATTS treatment for quarantine control of peach twig borer (PTB); 3) Determine if CATTS treatment can achieve quarantine insect kill when the insects are present in fruit that are in palletized boxes.

METHODS AND MATERIALS

Fruit Quality

CATTS treatments were performed using commercially-packed fruit. Fruit were warmed to the initial starting treatment temperature (23-25°C or 73-77°F) the night before the treatment was performed. Treatments were conducted using a CATTS (controlled atmosphere/temperature treatment system) chamber designed for treatment of agricultural commodities. Thermocouples were inserted into a number of fruit to monitor skin and pit surface temperatures during the treatment. Final chamber temperatures were maintained at 46°C (115°F) and total treatment durations were approximately 3 or 4 h (conditioning experiment) using a heating rate of 12°C (54°F)/h or 24°C (75°F)/h. Treatments were maintained until the pit surface had been at 45°C (113°F) for at least 15 min. All of the treatments had an atmosphere of 1% oxygen and 15% carbon dioxide. At least 20 fruit were used per replication in most cases, with a total of 4 replications (separate heat treatment runs) being performed for each treatment combination. Following treatment the fruit were placed into storage at 1°C (34°F) for 1 to 3 weeks.

Sensory Panel - The sensory work was conducted with TreeTop, Inc, Selah, WA. Five varieties of peaches and nectarines, with both yellow and white flesh, were represented. Fruit of commercial maturity were obtained from a packinghouse and CATTs treated using either a 12 °C (54°F)/h or a 24 °C (75°F)/h heating rate following an overnight period at 23°C (73°F). A portion of the fruit were untreated to act as controls. After treatment the CATTs fruit were placed into cold storage at 1°C (34°F) for 9 days after which the fruit were loaded into a van, transported to Yakima, WA in a 15-hour trip and again placed into a cold room held at 1°C (34°F). One variety was evaluated per day. Prior to evaluation the fruit were removed from cold storage and ripened at 23°C (73°F) for at least 3 days until the untreated and treated fruit had approximately the same degree of firmness. For the visual comparison 10 to 15 randomly selected fruit from each of the treatment groups (control and CATTs) were selected and placed into transparent glass dishes. Dishes with different treatments were placed adjacent to each other and panelists were asked to rate how different the groups of fruit were from each other by placing a mark on a 9-point numbered scale where 1 was the same and 9 was very different. From 24 to 30 panelists took part in the test. The same panelists then proceeded to an adjoining room for the taste evaluations. In these evaluations panelists rated the flavor and texture of sliced wedges. Fruit were presented in plastic cups to the panelists as 1/2 - 3/4 inch wedges that had been peeled and randomized. Either 3 or 4 slices were presented per treatment. These evaluations were conducted in private tasting booths divided by partitions with red lights. Unsalted crackers and water were used to cleanse the palate between samples. Panelists were initially asked to taste 3 samples and select the different sample in a forced choice triangle test. If differences between treatments were detected then panelists were asked to return in the afternoon when an attribute test was conducted to determine what the differences were due to. Observations for flavor (overall, peach/nectarine, sweetness and acidity) and texture (juiciness, mealiness, firmness) were all recorded on 9-point numbered scales. The final test conducted was a preference test where panelists were presented with samples and asked to rate the samples on a scale from 1 to 9 where 1=dislike extremely, 5 =neither like nor dislike and 9=like extremely.

CATTs conditioning – Ryan Sun and Elegant Lady peaches were obtained from a packing house. A portion of the fruit were immediately placed into storage at 20°C (68°F) for 48 h to condition them. The rest of the fruit were either warmed to 23°C (73°F) for preparation for treatment or placed into cold storage at 1°C (34°F) for later treatment. Both conditioned and non-conditioned fruit were subjected to CATTs treatment using a 12°C (54°F)/h heating rate and a total treatment duration of either 3 or 4h. Following treatment the fruit were placed into storage at 1°C (34°F) for 2, 3 or 4 weeks, after which the fruit were removed from cold storage and ripened until the fruit were at a firmness of 3 pounds or less. Fruit mealiness was estimated by measuring percent juice using the press method of Carlos Crisosto.

CATTs treatment of additional varieties - Following treatment fruit were stored for 2 weeks at 0 °C (32°F), ripened for 2 to 3 days (or more) and evaluated for quality. Surface injury was visually rated and fruit placed into classes ranging from 0 to 4 (0=no injury, 1=very slight, 2=slight, 3=moderate, 4=severe). Percent juice was used as a measure of flesh mealiness and determined using a press and weighing the expressed juice (Dr. Carlos Crisosto, UC Kearney). All fruit tested for percent juice were ripened to a firmness of 3 lbs. or less as determined by penetrometer measurements. The higher the percentage, the juicier the fruit. Internal browning of the flesh was visually rated from 0 (none) to 3 (severe). Juice from the fruit was used to

measure percent soluble solids and titratable acidity (reported as percent malic acid). Color was evaluated using a Minolta colorimeter by measuring the same spot on the skin before treatment and after storage and expressed in the L*a*b* scale as amount of change (post storage - pretreatment). Weight loss was calculated by weighing five fruit from the treatment lot before treatment and then the same fruit following storage and determining the difference and percentage weight loss.

RESULTS AND DISCUSSION

Fruit Quality

Sensory Panel (visual) – Results from the visual comparison are given in Table 1 with the 3 h treatment being the 12°C (54°F)/h heating rate and the 2.5 h treatment being the 24°C (75°F)/h heating rate. The untreated vs untreated comparison acted as the control with which to statistically compare the untreated vs. treated (3 or 2.5 h). All of the ratings were in the slightly different range. Panelists were able to discern a significant difference between untreated and treated fruit for some of the varieties but the actual rating differences were so small that we do not believe they are meaningful.

Table 1. Rating of difference from the untreated control for visual differences.

| Variety | Untreated vs. Untreated | Untreated vs 3 h Heat | Untreated vs 2.5 h Heat |
|------------------|-------------------------|-----------------------|-------------------------|
| Diamond Princess | 3.22 | 2.91 | No Test |
| Elegant Lady | 1.69 | 3.05* | 3.15* |
| Summer Sweet | 2.51 | 2.54 | 1.83* |
| Fire Pearl | 1.53 | 2.01 | 1.88 |
| Summer Bright | 1.60 | 2.38* | 2.37* |

* Indicates significant difference from control (untreated vs untreated) at 95% significance.
7.5-9.0 = extremely different; 5.5-7.4 = very different; 3.5-5.4 = moderately different;
1.1-3.4 = slightly different, 1.0 = no difference

Sensory Panel (Taste) - Initial taste tests using a triangle test indicated that panelists were able to determine that a difference in taste existed between treated and untreated fruit and between the two treatments (Table 2). In light of this finding attribute testing was conducted to determine which of the sensory attributes being evaluated had been altered by treatment. The results of this testing differed depending on variety and on treatment (Table 3). CATTs-treated (3h) ‘Diamond Princess’ peaches were thought by panelists to be less flavorful and slightly less acidic than the untreated control fruit. Similarly, ‘Elegant Lady’ peaches that were treated were believed to have less flavor than untreated fruit. In this case of this cultivar, however, a very slight increase in the mealiness of the flesh was also noted. For ‘Summer Sweet’ peaches a decrease in firmness and a slight loss of juiciness (2.5 h CATTs) were noted by the panelists to be the major changes caused by treatment. In the case of ‘Fire Pearl’ nectarines less flavor, including a decrease in sweetness, were the primary attributes found to differ between 3 h CATTs-treated and untreated

fruit. Fruit that were CATTS-treated for 2.5 h for this variety, on the other hand, differed not by flavor but due to textural issues. Acidity was the only sensory attribute significantly different from the control fruit for 3 h CATTS-treated ‘Summer Bright’ nectarines. Attribute testing was useful in detailing sensory differences between untreated and treated fruit, but in order to determine the effect of treatment on likeability of the fruit a separate preference test was conducted (Table 4). With the exception of ‘Summer Sweet’, for which likeability was not significantly altered by treatment, CATTS treated fruit were rated slightly lower in likeability than untreated fruit. Fruit treated using 2.5 h CATTS generally received a lower rating than fruit that had been treated using 3 h CATTS and for two of the four cultivars tested were rated in the “dislike” side of the rating scale. Although differences in likeability were detected by the panelists, these differences were fairly subtle as indicated by the small separations in ratings that were generally less than one unit out of a one to nine unit scale. Also, with the exception of ‘Summer Bright’ 2.5 h treatment, the panelists judged the likeability of the treated and untreated fruit to be fairly similar even when the difference was statistically significant. Differences of this magnitude, although noticeable to someone trained and skilled in detecting differences may not be noticeable to the average consumer.

Table 2. Triangle test for taste differences. Numbers indicate the proportion of panelists able to determine a difference between treatment comparisons.

| Variety | Untreated vs 3 hrs Heat | Untreated vs 2.5 hrs Heat | 3 hrs Heat vs 2.5 hrs Heat |
|------------------|----------------------------|------------------------------|-------------------------------|
| | Number of Panelists | | |
| Diamond Princess | 19 of 29* | No Test | No Test |
| Elegant Lady | 17 of 30* | 17 of 30* | 17 of 30* |
| Summer Sweet | 15 of 29* | 15 of 29* | 15 of 29* |
| Fire Pearl | 14 of 25* | 15 of 25* | 10 of 25 |
| Summer Bright | 13 of 24* | 23 of 24* | 18 of 24* |

* a significant result (95% level).

Table 3. Difference ratings of flavor and textural attributes for the treatment comparisons.

| Variety | Treatment Comparison | Flavor Attributes | | | | Texture Attributes | | |
|------------------|--------------------------|--|--------------------|-----------|---------|--------------------|-----------|-----------|
| | | Overall Flavor | Peach/Nect. Flavor | Sweetness | Acidity | Juiciness | Mealiness | Hard/Firm |
| Diamond Princess | Untreated vs 3 hr Heat | 3.81* | 4.01* | 4.51 | 4.23* | 4.78 | 5.22 | 4.96 |
| | Untreated vs 2.5 hr Heat | Not performed-No fruit | | | | | | |
| | 3 hrs vs 2.5 hrs | Not performed-No fruit | | | | | | |
| Elegant Lady | Untreated vs 3 hr Heat | 4.33* | 4.21* | 4.71 | 4.62 | 4.52 | 5.52* | 4.84 |
| | Untreated vs 2.5 hr Heat | 4.34 | 4.29* | 5.02 | 4.72 | 4.56 | 5.80* | 4.59 |
| | 3 hrs vs 2.5 hrs | 5.20 | 5.21 | 5.05 | 4.71 | 5.23 | 5.23 | 4.73 |
| Summer Sweet | Untreated vs 3 hr Heat | 5.25 | 5.47 | 5.12 | 5.05 | 5.09 | 5.28 | 4.30* |
| | Untreated vs 2.5 hr Heat | 4.81 | 4.71 | 5.07 | 4.98 | 4.45* | 5.30 | 4.40* |
| | 3 hrs vs 2.5 hrs | 4.84 | 4.78 | 5.15 | 4.84 | 4.84 | 5.21 | 4.88 |
| Fire Pearl | Untreated vs 3 hr Heat | 3.88* | 3.55* | 3.46* | 4.87 | 4.42 | 5.48 | 4.85 |
| | Untreated vs 2.5 hr Heat | 4.52 | 4.45 | 4.60 | 4.77 | 4.75 | 5.73* | 4.25* |
| | 3 hrs vs 2.5 hrs | No significant difference in triangle test | | | | | | |
| Summer Bright | Untreated vs 3 hr Heat | 4.61 | 4.71 | 4.47 | 5.69* | 4.72 | 5.03 | 5.11 |
| | Untreated vs 2.5 hr Heat | Not performed - but significant difference in triangle test | | | | | | |
| | 3 hrs vs 2.5 hrs | Not performed - but sSignificant difference in triangle test | | | | | | |

*significant difference @ 95%

8-9 = very much more; 7-8 = moderately more; 6-7 = slightly more; 5-6 = very slightly more; 5 = same; 4-5 = very slightly less;

3-4 = slightly less; 2-3 = moderately less; 1-2 = very much less

Table 4. Preference tests indicating the degree of likeability of the taste of untreated and CATTS-treated fruit. 9=like extremely, 8=like strongly, 7=like moderately, 6=like slightly, 5=neither like nor dislike, 4=dislike slightly 3=dislike moderately, 2=dislike strongly, 1=dislike extremely.

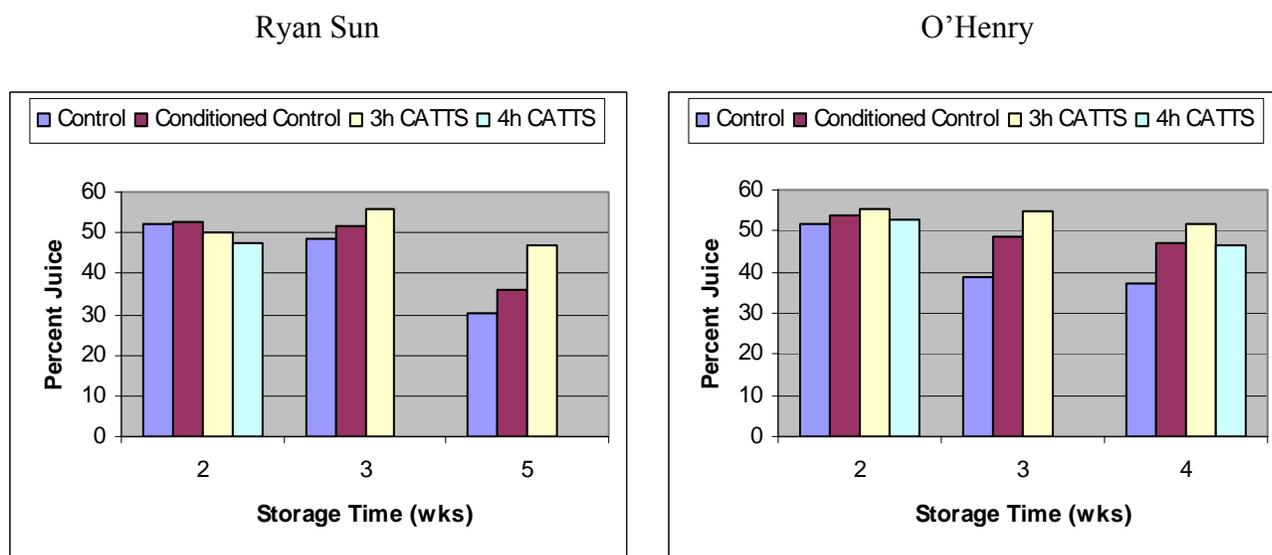
| Variety | Untreated | 3 h Heat | 2.5 h heat |
|------------------|-------------------|-------------------|--------------------|
| Diamond Princess | 6.87 ^a | 6.03 ^b | No Test |
| Elegant Lady | 6.59 ^a | 5.17 ^b | 4.86 ^b |
| Summer Sweet | 6.04 ^a | 5.86 ^a | 5.39 ^a |
| Fire Pearl | 6.85 ^a | 5.20 ^b | 5.70 ^{ab} |
| Summer Bright | 7.52 ^a | 5.91 ^b | 3.52 ^c |

^{a,b,c} sample scores in rows with different superscripts are significantly different.

CATTS conditioning – For the variety ‘Ryan Sun’ CATTS-treated fruit was slightly less juicy than control or conditioned (pre-ripened) fruit following two weeks of cold storage at 1°C (34°F) (Figure 1). After three weeks, however, CATTS-treated fruit was juicier than either control or conditioned fruit. It should be noted that all of the fruit from two and three weeks of storage were of a percent juice that would be considered quite juicy. Following five weeks of storage the control and conditioned fruit had 30 and 36% juice, respectively, and were mealy, while the CATTS-treated fruit had 47% juice and were still juicy. CATTS-treatment was also superior in maintaining free juice during long term storage (3 and 4 weeks) of ‘O’Henry’ peaches (Figure 1).

All treatments were fairly equivalent in percent juice levels in ‘O’Henry’ following 2 weeks of storage. As has been seen previously, varieties that are susceptible to internal breakdown may benefit from CATTs-treatment in terms of retaining juiciness. Given that some potentially negative side effects of treatment exist, such as enhancement of existing surface injury, it seems unlikely, however, that this treatment would be used solely as another means to condition fruit, but instead the positive effect can be seen as a useful benefit from quarantine-treating the fruit.

Figure 1. Percent juice following either conditioning or CATTs treatment, cold storage and subsequent ripening.



CATTs treatment of additional varieties - Surface injury data from a number of varieties not previously evaluated for tolerance to CATTs treatment is presented in Table 5. Although the full complement of quality data was collected from these varieties only surface injury will be presented as there was little or no meaningful differences in the other quality parameters. Injury was low and in acceptable levels. As has been observed previously, those varieties with higher initial (control) injury ratings had the highest amount of injury following CATTs.

Table 5. Surface injury rating on some varieties not previously evaluated for tolerance to CATTS.

| Cultivar | Treatment | Surface Injury |
|--------------|-----------|----------------|
| Diamond Ray | 0h | 0.6 |
| | 2.5h | 0.9 |
| | 3h | 0.9 |
| Flavorcrest | 0h | 1.0 |
| | 2.5h | 1.6 |
| | 3h | 1.8 |
| Ruby Pearl | 0h | 2.4 |
| | 2.5h | 2.1 |
| | 3h | 2.2 |
| Ruby Diamond | 0h | 0.3 |
| | 2.5h | 0.6 |
| | 3h | 1.1 |
| Fancy Lady | 0h | 1.7 |
| | 2.5h | 1.8 |
| | 3h | 2.1 |

Ratings: 0 = no injury, 1 = very slight, 2 = slight, 3 = moderate, 4 = severe. Average ratings of 2.5 and above are considered unmarketable.

Bottom line for Fruit Quality Work

Sensory testing indicated that trained panelists can tell a difference between untreated and CATTS-treated fruit and generally they prefer the taste of untreated fruit for a variety of reasons that depend on the variety. Given the small differences in the taste ratings (especially with the 3 h treatment), however, it is likely that a consumer would not notice any difference. Visually the fruit were not different to any meaningful degree either. Some varieties can be successfully conditioned using CATTS but it may not be worth the risk of some of the known side effects of treatment to treat for only this reason.

Insect Work

Submission of confirmatory and efficacy report to USDA/ARS – A report was submitted at the end of 2003 to Dr. Ken Vick (National Program Staff) as an initial step in the process to certify the treatment.

PTB quarantine treatment – Peach twig borer (PTB) shipments were received from the Kearney Agricultural Station and work is currently ongoing to build up a colony to determine the effective CATTS treatment for this insect.

System to assess insect mortality in response to CATTS – A new system was developed to enable a more rapid and easier assessment of insect mortality in response to CATTS. The system

utilizes two programmable water baths and enables simultaneous treatment of insects contained in test tubes under air and controlled atmosphere conditions. Heating rates simulate fruit heating profiles obtained from actual CATTS treatments. Testing of the new system this season has involved completing most tolerant stage assessment for OFM. Work on CM and PTB are being initiated.

Commercial CATTS treatment - Testing was begun to determine if the large-scale CATTS chamber in George, WA was capable of providing the atmospheres and temperatures needed for CATTS treatments. Initial work showed that the unit was able to achieve quarantine security against codling moth and oriental fruit moth placed into apples inside bins. It was found that peaches and nectarines packed in standard California boxes heat at a similar rate to apples in a 500 pound bin but slower than fruit packed into RPC containers. Based on the ability of the system to heat fruit in packed boxes a full pallet load of Washington peaches (Zee Lady) packed into California boxes with plastic trays were CATTS-treated. Approximately 2000 4th instar OFM were placed into the center of the pallet to test efficacy of the treatment. Fruit were stored at 1°C (34°F) for 10 days, ripened and evaluated for quality. Results indicated that although the insects were killed the treatment caused a sizeable number of the fruit to become mealy (Figure 2). Temperatures that were excessively high during the run could have been responsible for this result.

Figure 2. Percentage of mealy peaches in boxes following George, WA commercial CATTS treatment, 10 d storage at 32 to 34 °F and subsequent ripening. Squares represent boxes of fruit that were stacked on the pallet. The percentages indicate the percentage of mealy fruit within each box based upon 20 fruit samplings.

| | | | | | | | | |
|-----|-----|-----|-----|--|-----|-----|-----|-----|
| 25% | 5% | | 25% | | 24% | 20% | | 25% |
| 35% | | | 25% | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | 60% | | | | | |
| 54% | | | 25% | | 30% | | | 25% |
| 45% | 25% | 40% | 10% | | 60% | 45% | 25% | 40% |
| | | | | | | | | |
| | | | | | | | | |
| 30% | | | 5% | | 65% | | | 30% |

Front boxes on pallet

Rear boxes on pallet

Note: Controls (untreated) were not mealy