Controlled Atmosphere/High Temperature Forced Air: A Non-Chemical Quarantine Treatment for Stone Fruit

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ABSTRACT

Three white nectarine varieties (Fire Pearl, August Pearl and Arctic Pride) were treated with forced hot air (final chamber temperature 115 ºF) combined with controlled atmosphere (1 % oxygen, 15 % carbon dioxide) using a boxed/palletized treatment format in a large semi-commercial chamber. Three pallets (three separate runs, 160 boxes per run) were treated for each variety, using temperature probes distributed uniformly among the boxes to measure core temperatures. Heating was found to be quite rapid and treatments could be completed in 4 hours with size 50 fruit. Boxes on the outside as well as on the front of the stack tended to heat faster, although the heat distribution was more even that in previously-tested two-layer and volume-filled box configurations. Decay and surface injury were enhanced in Fire Pearl but were not influenced to any great degree in the other two varieties. Both August Pearl and Arctic Pride developed a significant amount of internal browning around the pit in the treated fruit. It is possible that this internal quality issue can be minimized by immediate forced air cooling of the product following treatment or by using a lesser heating rate. Entomological work is ongoing with the oblique banded leaf roller, peach twig borer, European spider mite and two-spotted spider mite to determine if CATTS is an effective treatment for these pests. Plans are underway to examine the susceptibility of the light brown apple moth to CATTS as well as to perform efficacy tests with Oriental fruit moth in boxed nectarines using the large treatment chamber.

INTRODUCTION

Research funded by CTFA in past seasons has shown that treatment using high temperature forced air combined with low oxygen and high carbon dioxide (also known as CATTS) is a feasible means of achieving quarantine security against a variety of insect pests when performed under laboratory conditions. In order for the treatment to be economically viable it needs to be useable under conditions that fit into current industry practices. Late in the 2007 season a treatment chamber was acquired that is capable of treating large quantities of boxed/palletized fruit. The ability to treat fruit in this manner would be a significant step in showing that CATTS treatment could be a useful tool to the stone fruit industry. The objective of the research this season was to utilize the large treatment chamber to determine if fruit quality can be maintained following CATTS treatment of fruit in this manner. Also, further entomological work was continued to expand the list of insect pests that can be controlled using the CATTS treatment.

METHODS

Large chamber preliminary testing with oranges
Prior to the beginning of the stone fruit season a series of tests were conducted using navel oranges (similar in size to size 50 fruit) to help answer a number of questions regarding treatment in the large chamber. All of these tests were done in the large treatment chamber without the addition of a controlled atmosphere. One comparison that was made was between single- and double-layer boxes packed on a single pallet to test whether or not the single-layer arrangement would allow faster and more uniform heating of the fruit. Another comparison looked at the effect of blocking off airflow through one of the two pallets to see if greater airflow through the remaining boxes would lower treatment times and increase uniformity in heating. The final comparison looked at the effect on fruit core heating rates of doubling the chamber heating rate from 12 to 24 ºC/hour.

Large chamber testing with stone fruit
Commercially-packed fruit (Fire Pearl, August Pearl and Arctic Pride) were obtained from a packing house and fruit core temperatures were adjusted to 23 °C by placing packed fruit into an environmental room set at 23 °C or higher overnight prior to the run. Arctic Pride was size 48, while the other two varieties were size 50. Fruit were repacked into single-layer boxes with venting on the sides of the box. Fruit were stacked into the front of the chamber in standard configuration, with 80 boxes on the pallet and temperature probes distributed throughout the load (Figures 2 and 3). In the position of the rear pallet empty boxes with the vents taped over were stacked to reduce the amount of fruit needed for each treatment. The initial chamber temperature (approximately 23 °C) was rapidly achieved by heating at 60 °C/hour. Dew point was maintained during the entire run at 2 °C below the chamber temperature. Fan flow through the box stacks reversed every 15 minutes. The chamber temperature was held at 23 °C until the controlled atmosphere reached 1% oxygen and 15% carbon dioxide, which required at least 30 to 60 minutes. When the correct controlled atmosphere was reached the chamber was heated at 24 °C/h until the chamber reached 46 °C (115 °F) where it was held until all probed fruit core temperatures had reached and remained at 43.8 °C for 30 minutes. This was the end of the treatment. Three replicates (separate runs) were completed for each of the three varieties tested, with one run being completed per day.

Following 2 and 3 weeks of cold temperature storage, treated and control fruit were taken from cold storage and ripened until firmness readings for the control fruit were 3 pounds or less as determined by a penetrometer (U.C. Firmness Tester) with a 7.9 mm tip. Five fruit from each treatment lot that had been randomly selected, weighed and marked prior to treatment were again individually weighed. Weight loss was calculated by subtracting the weights from the pretreatment values and a mean weight loss for the five fruit determined. Using a chromameter (Minolta, Ramsey, NJ) coloration of the external surface of the same five fruit was measured and expressed as L* C* h color coordinates. Measurement was performed inside of a single circled region on the fruit in an area of representative ground color. The same circled area had also been measured prior to treatment enabling determination of color change due to treatment and storage. Color and weight was not determined for Fire Pearl. Fruit were then subjectively rated for the amount of surface injury present and placed into classes where 0 = none, 1 = very slight, 2 = slight, 3 = moderate and 4 = severe. An average rating index was calculated by multiplying the number of fruit in each class by the class number (0-4), summing, and dividing by the total number of fruit in each class. The percentage of marketable fruit (on the basis of surface injury alone) was estimated by adding together the number of fruit with moderate or greater injury and dividing by the total number of fruit. After inspection for surface injury the fruit were sliced in half and rated for browning around the pit, with moderate and severe ratings being considered to be unacceptable to consumers (see Figure 4). Percent internal browning was calculated by dividing the number of fruit with moderate and severe browning ratings by the total number of fruit. Soluble solids concentration (SSC) was determined from the juice using a temperature corrected digital refractometer (Atago, Kirkland, WA). From the same juice titratable acidity (TA) was measured by diluting 10 mL of juice to a total volume of 25 mL with distilled water and then titrating the diluted juice to pH 8.1 with 0.1 N NaOH. The volume of NaOH required was recorded and a calculation made to convert to a percent malic acid basis.

RESULTS

Large chamber preliminary testing with oranges

Thes tests with oranges were used to get a head start on establishing what treatment conditions were to be used for testing during the 2008 season. Going from a double-layer to single-layer box was able to reduce the treatment time needed by more than an hour and was effective in lessening the differences in core temperatures between fruit in various boxes throughout the pallet stack. Enhancing the airflow through the boxes by blocking off one of the two pallets, on the other hand, had relatively no effect on the treatment. It is unknown if an additional increase in airflow over what was achieved would have had an effect. Increasing the chamber heating rate from 12 to 24 ºC/hour acted to reduce treatment times and brought the fruit heating rates more in line with what had been previously observed in previous work with the small laboratory chamber with a 12 ºC/hour heating rate. As a result of these preliminary tests it was decided to conduct the upcoming stone fruit tests exclusively in single-layer boxes using a chamber heating rate of 24 ºC/hour.

Large chamber testing with stone fruit

Treatment runs with size 50 fruit (Fire Pearl and August Pearl) were very rapid, requiring approximately 3.5 hours of heating. When size 48 fruit were used (Arctic Pride), the required heating time increased to 5 hours. This large increase in time was not only due to the greater mass of the fruit but also due to the addition of “penalty” time as mandated by the CATTS protocol in the APHIS manual.

The predominant effect of treatment in Fire Pearl was an increase in surface injury and a corresponding increase in decay (Table 1A). The decay was almost exclusively found on the portion of the fruit that was covered by the tray, likely as a result of the additional trapped moisture. This damage and decay resulted in nearly 25% of the fruit being unmarketable. The treatment slowed ripening (greater firmness) but did not affect brix, acidity or internal browning. The presence of some wrinkling of the skin was slight in both control and treated fruit but was slightly less in the treated fruit. No effect of position of fruit within the pallet stack was observed for surface injury, decay or marketability (Table 1A, Figure 1 diagram), although slight differences were seen in wrinkle and acidity.

Fruit core heating rates recorded within the pallet stack during the Fire Pearl treatment runs varied depending on where the fruit were positioned within the stack (Table 1B, Figure 1 diagram). Fruit in boxes toward the center (Inner) took a longer amount of time to reach a given temperature than fruit in boxes toward the outside (Outer). Whether the fruit were in boxes toward the front or rear of the pallet rather than the front also made a difference, although to a lesser degree.

In contrast to Fire Pearl, CATTS treatment did not affect either surface injury or the decay rate of August Pearl, although the percentage of marketable fruit was slightly less in the treated fruit (Table 2). Slight changes as a result of treatment were observed in firmness, acidity and peel color. The most important impact of treatment on this variety was an increase in internal browning around the pit (Figure 4). There was little or none in the controls while over 11% of the treated fruit were damaged in this manner. Analysis of box position (Table 2) indicated that those fruit in the outside of the pallet stack had a greater amount of internal browning. This was likely due to the fact that those fruit received a greater amount of heat.

Internal browning was also strongly enhanced by treatment in Arctic Pride (Table 3) with over 30% of the fruit being negatively affected. In contrast to August Pearl, there were no significant effects of box position within the stack noted. It is possible that the longer treatment times required for this variety acted to enhance this disorder. Surface quality was excellent following treatment and there was only a small amount of decay noted in either treated or non-treated fruit. None of the other quality parameters were influenced by the CATTS treatment.

Entomological Research

We have subjected the egg and the larvae of oblique banded leafrollers (OBLR) to simulated CATTS treatments using a heating block with the capacity to apply a controlled atmosphere. We used a heating rate of 24°C/hr from 23° to 44.5° under normal air or controlled atmospheres (1% O_2, 15% CO_2). In general, when the mortality data of OBLR is compared to oriental fruit moth, it is apparent that OBLR is less tolerant to the combination heat and controlled atmosphere treatments (CATTS) than Oriental fruit moth (OFM). Of the immature stages of OBLR, it appears that the eggs and early instars of OBLR are more tolerant than the other stages. The most tolerant stage of OFM, the 4th instar, has approximately 70% mortality at 1.5 h of treatment under a 1% O_2, 15% CO_2 atmosphere. OBLR overall mortality under these conditions was greater than 99%. We are still in the process of completing this data set for including of all time points and immature stages for the basis of a publication. We will also confirm these data using in-fruit treatments this summer and will treat all life stages using the current CATTS treatment for nectarines.

We have tested OFM in the CA heat block using the heating profile obtained from last summer's large scale test using palletized boxes of nectarines. We are developing a mathematical model to predict treatment efficacy (100% mortality) using the CA heat block. We will test this model with in-fruit treatments prior to our efficacy trial in Parlier this spring/summer.

We have arranged to bring peach twig borer (PTB) into culture in the laboratory. We are working with Steve Tebbets at the USDA-ARS lab in Parlier to help us establish the culture at YARL. We have also located a native population of PTB at the YARL research farm in Moxee, WA. We will collect naturally infested fruit from the Moxee farm this summer and treat half of it with CATTS and use the other half to begin a colony in the lab. We hope to be more successful in the rearing of PTB with the use of our new environmental growth cabinet provided last year by CTFA. This cabinet is currently being used to rear OBLR and had provided us with a very robust colony.

European red mite (ERM) and two-spotted spider mite have been made into colonies in the lab. We will be using the CA-water bath system to test for CATTS tolerance in the different stages of this pest. Previous research indicates that the diapausing eggs of ERM are more CATTS tolerant than the other life stages, but that they were not able to tolerate the 12°C/h 46°C CATTS treatment established for nectarines. Research by other labs indicated that two-spotted spider mite diapausing females are more tolerant to heat and CA than the other stages. We will test that hypothesis this spring and summer.

We are working with Dr. Peter Follett on determining whether light brown apple moth (LBAM) is as susceptible to CATTS as previously reported by researchers in New Zealand. Dr. Follett has been assisted by us in modifying his heat block to add a humidified controlled atmosphere. He plans to test the immature stages of LBAM in the CA heat block this winter. Dr. Follett also has the twin CATTS chamber to our research unit and we plan to send him nectarines this summer for testing of infested fruits.

We are coordinating with Steve Tebbets at the Parlier lab to help us in rearing of OFM for our efficacy trials this spring/summer. We have determined that it will be more cost effective is we send eggs and artificial diet to Parlier for rearing to 4th instar so that we can fly down and perform the two efficacy tests to prove that the CATTS treatments of boxed nectarines will kill OFM. We plan to use OFM since both codling moth and OFM are comparable in CATTS tolerance and we get more OFM in the fruit than codling moth. In addition, OFM is more fecund and thereby less expensive to rear. We plan to treat and kill over 5,000 4th instar OFM for the efficacy trials.

CONCLUSIONS

Although, it was shown to be possible to heat boxed fruit in a fairly rapid manner, the results from the fruit quality experimentation were disappointing in that all three of the varieties that were tested were significantly damaged by the treatment. This could be due to the fact that some of the fruit in the pallet experienced an excessive amount of heating due to the difficulty in forcing heated air through the palletized boxes. It is possible that alteration of the heating protocol could eliminate the damage and still maintain an efficacious quarantine treatment. Experimentation will be continued in the 2009 season with this as an objective.

Table 1A. Fire Pearl™ nectarine fruit quality following large-scale CATTS treatment. Comparisons followed by different letters are significantly different.

Treatment	Surface Injury (Rating)^z	Decay (%)	Marketable (%)^y	Wrinkle (%)	Brix	Firmness (lbs)	Acidity (%)	Internal Browning (%)^x
Control	0.59a	7.9a	90.3a	6.0a	12.8a	2.1a	0.48a	0.10a
Treated	0.98b	19.1b	76.4b	2.6b	13.4a	5.2a	0.39a	0.17a
Box Position ^{w}								
Inner	0.95a	19.7a	76.2a	2.9a	13.6a	5.7a	0.39a	0.23a
Outer	1.02a	18.6a	76.6a	2.5a	13.3a	5.2a	0.40a	0.11b
Front	1.03a	19.2a	75.4a	4.0a	13.7a	4.9a	0.38a	0.19a
Rear	0.94a	19.0a	77.4a	1.2b	13.2a	6.0a	0.41b	0.17a
Upper	1.01a	20.2a	75.1a	1.6a	13.6a	5.7a	0.40a	0.16a
Lower	0.96a	18.0a	77.8a	3.6b	13.3a	5.1a	0.39b	0.20a

^{z}Ratings from 0 (no injury) to 4 (severe)
^{y}Refers to surface quality only
^{x}Percentage of fruit with unacceptable internal browning
^{w}See Figure 1 for description of box positions

Table 1B. Fire Pearl™ nectarines. Differences between box temperatures. Comparisons followed by different letters are significantly different.

Box Position in Stack[z]	Time to Reach 110 °F (minutes)
Inner	145a
Outer	134b
Front	137a
Rear	142b
Upper	140a
Lower	138a

[z]See Figure 1 for description of positions

Table 2. August Pearl™ nectarine fruit quality following large-scale CATTS treatment. Comparisons followed by different letters are significantly different.

Treatment	Surface Injury (Rating)[z]	Decay (%)	Marketable (%)[y]	Wrinkle (%)	Brix	Firmness (lbs)	Acidity (%)	Internal Browning (%)[x]	Peel Color (hue)	Weight Loss (%)
Control	0.52a	4.1a	94.9a	10.9a	15.0a	2.2a	0.24a	0.5a	7.73a	9.04a
Treated	0.72a	8.4a	87.1b	8.1a	15.2a	3.9b	0.27b	11.6b	10.45b	9.28a
Box Position [w]										
Inner	0.71a	8.4a	87.1a	10.5a	15.2a	3.7a	0.28a	14.4a	9.90a	8.96a
Outer	0.73a	8.4a	87.0a	8.7a	15.3a	4.1b	0.27b	19.1b	10.45a	9.66a
Front	0.72a	9.0a	86.2a	10.6a	15.1a	3.9a	0.28a	16.8a	10.35a	8.96a
Rear	0.71a	7.8a	87.9a	8.5a	15.3a	3.9a	0.27a	16.1a	9.94a	9.66a
Upper	0.74a	8.3a	87.1a	23.9a	15.3a	3.9a	0.28a	15.9a	10.24a	9.24a
Lower	0.69a	8.5a	87.0a	8.9a	15.1a	3.9a	0.27a	17.0a	10.04a	9.32a

[z]Ratings from 0 (no injury) to 4 (severe)
[y]Refers to surface quality only
[x]Percentage of fruit with unacceptable internal browning
[w]See Figure 1 for description of box positions

Table 3. Arctic Pride nectarine fruit quality following large-scale CATTS treatment. Comparisons followed by different letters are significantly different.

Treatment	Surface Injury (Rating)[z]	Decay (%)	Marketable (%)[y]	Wrinkle (%)	Brix	Firmness (lbs)	Acidity (%)	Internal Browning (%)[x]	Peel Color (hue)	Weight Loss (%)
Control	0.90a	1.7a	95.0a	18.3a	14.9a	1.6a	0.22a	3.0a	8.15a	4.8a
Treated	1.15a	2.0a	88.6a	7.0a	14.9a	5.0b	0.22a	30.9b	8.96a	5.4a
Box Position [w]										
Inner	1.15a	1.7a	89.7a	7.0a	15.0a	4.9a	0.23a	27.4a	8.98a	5.30a
Outer	1.15a	2.4a	87.2a	7.0a	14.8a	5.0a	0.22a	31.5a	8.93a	5.45a
Front	1.17a	2.2a	88.3a	7.3a	14.9a	5.3a	0.22a	30.1a	9.02a	5.83a
Rear	1.12a	1.9a	88.8a	6.7a	14.9a	4.7a	0.23a	28.5a	8.90a	4.92b
Upper	1.17a	2.2a	88.4a	6.7a	15.0a	5.2a	0.23a	30.0a	8.81a	5.46a
Lower	1.13a	1.9a	88.8a	7.3a	14.7a	4.8a	0.22a	28.3a	9.14a	5.27a

[z]Ratings from 0 (no injury) to 4 (severe)
[y]Refers to surface quality only
[x]Percentage of fruit with unacceptable internal browning
[w]See Figure 1 for description of box positions

Figure 1. Diagram of 160 boxes on a single pallet as used in large-scale CATTS treatments

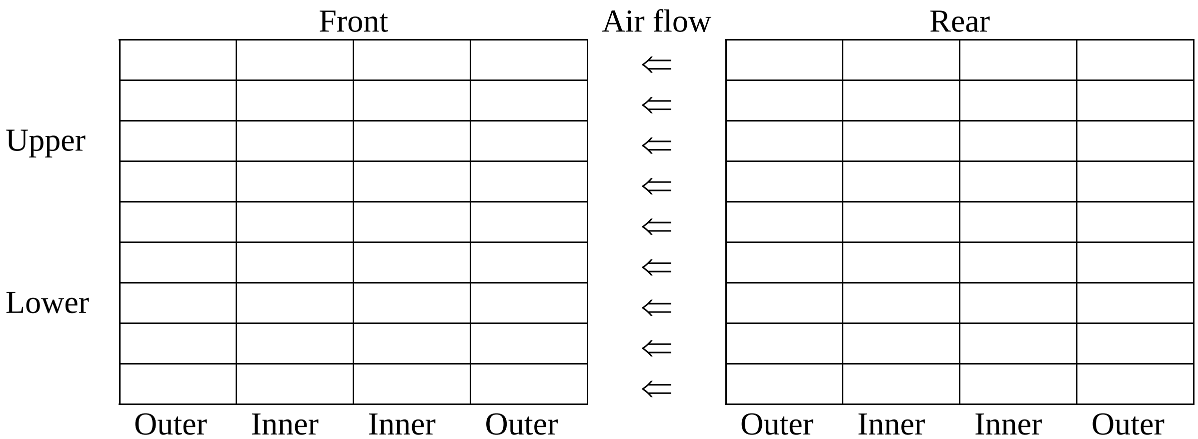

Figure 2. Picture of CATTS chamber partially-loaded with single-layer boxes

Figure 3. Single-layer box in chamber with temperature probe.

Figure 4. Flesh browning/translucence surrounding the pit following ripening.