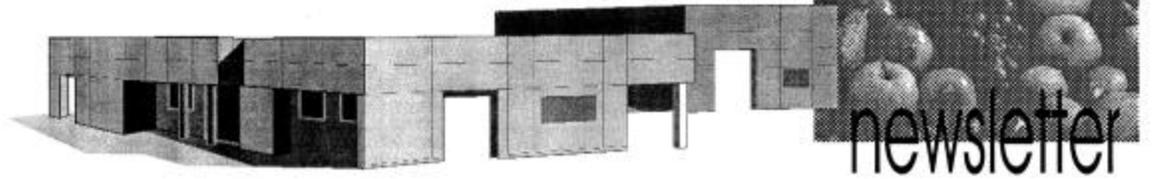




# Central Valley **POSTHARVEST**



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## PEACH AND NECTARINE INKING UPDATE IN CALIFORNIA

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 University of California

Inking or skin discoloration on peach and nectarine fruits has become an increasingly frequent problem in the last decade in California, Washington, Georgia, South Carolina, and Colorado. Inking is also a problem in other production areas in the world

including Italy, Australia, Argentina, and Chile. Inking symptoms appear as discolored brown and black spots and/or longitudinal stripes, and are restricted to the skin. Although inking affects only the fruit’s cosmetic appearance, this disorder causes considerable losses to the peach and nectarine industry each year.

Through our anatomical studies, we learned that the type of physical injury associated with inking is abrasion. Damaged skin cells (epidermis), where the anthocyanin/phenolic pigments are located, were collapsed while the underlying fleshy cells (mesocarp cells)

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remained intact. Unfortunately, abrasion injury frequently occurs during harvest and hauling operations, and it is very difficult to eliminate. Abrasion damage releases these anthocyanin/phenolic pigments, allowing a reaction with heavy metal contaminants that are located on the surface of the fruit. We found that iron, copper, and aluminum were the most deleterious contaminants of those studied in inducing inking on abraded fruit. Approximately 5 ppm iron was enough to induce inking at the common physiological fruit pH of about 3.5. Such fruit surface contamination generally occurs within 15-21 days before harvest, during harvest or packing operations. Foliar nutrient, fungicide, and insecticide preharvest sprays can act as sources of contamination for inking development depending on the type of chemical and preharvest application interval. Last season, we had cases in which inking was induced by the fruit (wax) additives during the packaging operation. Additionally, we observed some over waxing that caused inking and pitting symptoms – especially on nectarines.

We completed our inking research by analyzing several pesticides, fruit additives, and foliar nutrient pesticides currently used in the tree fruit industry for presence and amount of heavy metals. Several chemicals such as insecticides, fungicides, foliar nutrients and fruit waxing coatings had inking activity. Based on their iron concentration, we classified these selected products in groups based on their potential for inducing inking development. It is important to point out that this potential inking activity screening test can vary according to product lots and years, and as such, it is important to send chemical samples for iron and copper analysis to your local laboratory if there is a suspicion that they may be contributing to inking development. Such information is fundamental in understanding different inking situations, and in generating recommendations to reduce inking in the California stone fruit industry.

## Recommendations

Based on our research work the following recommendations are suggested to help growers reduce inking problems in yellow/white flesh cultivars.

Reduce fruit abrasion damage.

- Handle fruit gently.
- Avoid long hauling distances.
- Keep harvest containers free of dirt.
- Morning picking is better than late picking.

Reduce contamination of fruit.

- Keep harvesting equipment clean.
- Avoid dust contamination on fruit.
- Check spray water quality for heavy metal (Fe and Cu) contaminants
- Do not spray foliar nutrients containing heavy metals within 21 days before harvest (unless there is a known deficiency).
- Check for potential heavy metal (Fe and Cu) contaminants in insecticides, fungicides and foliar nutrient sprays.
- Check for potential heavy metal (Fe and Cu) contaminants in your packing operation such as washer water, hydrocooling water; fruit coatings, waxes, etc.
- Keep water pH below 8.0 during your packing operation.

In the case of a possible inking situation with peach and/or nectarine, delay packaging for 48 hours to detect fruit inking damage during grading. It takes at least 24 hours for inking damage to develop to maximum expression.

As a short-term solution, we suggest chemical manufacturers (of foliar nutrients, fungicides and insecticides) develop preharvest application intervals to avoid inking.

As a long-term solution, we suggest chemical manufacturers attempt to identify and remove possible sources of contamination from products that may contribute to inking.

These same recommendations are also valid for white flesh peaches and nectarines. For these white flesh cultivars, it is essential, if fruit are wet, to maintain high levels of at least 100-ppm active chlorine (HOCL) and pH 7-8 during the washing and hydrocooling processes.

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## EVALUATION OF DIFFERENT BOX LINERS FOR THE CALIFORNIA 'BING' CHERRY INDUSTRY

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### Abstract

Market life potential of 'Bing' cherries packed with different modified atmosphere packaging (MAP) box liners was compared with solid (commercial) and perforated box liners after

15, 30 and 45 days of storage at 34°F followed by a four-day simulated shelf life period at 68°F. Three high CO<sub>2</sub>/O<sub>2</sub> ratios were reached with the use of MAP box liners such as LifeSpan (8% CO<sub>2</sub>/5% O<sub>2</sub>), (10% CO<sub>2</sub>/5% O<sub>2</sub>) and MAP 012 (8% CO<sub>2</sub>/10% O<sub>2</sub>) than with the solid (4% CO<sub>2</sub>/16% O<sub>2</sub>) or perforated box liner (0% CO<sub>2</sub>/20% O<sub>2</sub>). Ethylene levels within the box were very low (approximately 150 ppb) during all the storage period. The incidence of decay was significantly lower with any of the MAP box liners, even the solid box liner, compared with fruit packed in perforated box liners at any evaluation time. In a short-term shipment (within 15 days), cherries packed in the FRESHBAG had the lowest decay (4.9%), followed by cherries packed using the solid (10.8%) and LifeSpan (7.5%) box liners. However, the use of the solid box liner protected cherries from stem browning, skin color darkness, and firmness losses as well as any of the MAP treatments. In a long-term shipment, the use of solid box liners did not protect cherries from decay development and other deterioration factors as well as any of the MAP treatments. MAP delayed 'Bing' cherry deterioration such as decay, stem browning, skin color darkness, firmness losses and TA degradation. Most of these beneficial effects were also carried over during the warming period at 68°F that simulated shelf life.

### Introduction

Extending storage/overseas shipping life and assuring good arrival is an essential requirement for the California cherry industry. This will allow our industry to access long distance markets with high quality fruit and low transportation costs. In addition to good temperature management practices, new technology is needed to maintain green stems, and to avoid skin color darkness and decay. The use of controlled atmosphere (CA) technology during storage and shipment is being used successfully by the cherry industry. High (20-25%) CO<sub>2</sub> and ambient O<sub>2</sub> in combination with 32°F storage was developed by Patterson and Melstad (1977) for 'Bing'

cherries. Recently, a combination of (3-10%) O<sub>2</sub> with (10-12%) CO<sub>2</sub> has been recommended by Kader (1997). He also suggested a critical value of less than 1% for O<sub>2</sub> to avoid 'Bing' skin pitting and "off flavor". CO<sub>2</sub> equal to or higher than 30% has been related with brown skin discoloration and "off flavor" (Zoffoli et al., 1988). Modified atmosphere packaging (MAP) is an alternative technology for CA storage/shipment where the final O<sub>2</sub> and CO<sub>2</sub> concentrations are generated by the use of equipment. In a MAP system, the new atmosphere is attained by the respiration of the fruit, box liner permeability, and fruit temperature. At a given temperature, the two gases reach steady concentrations (plateau) when the rate of gas permeation through the package film equals the rate of respiration. The beneficial effect of high CO<sub>2</sub> while maintaining a high level of O<sub>2</sub> (3-10%) to avoid injury is the target for MAP on cherries. 'Bing' cherries packed using Xtend MAP film stored well up to two months at 32°F but quality rapidly deteriorated during the third month of storage (Lurie and Aharoni, 1997). Previous work with Chilean 'Bing' cherries showed that there were no significant differences in cherry market life by using Viewfresh, Freshold, FRESHBAG and MAP 012 box liners (Zoffoli et al, 1988). Also, during that work, it was clear that MAP box liner benefits could be obtained by using a manual hermetic sealing system.

The commercial use of MAP on cherry has been developed rapidly in the Pacific Northwest (USA) to deliver high quality cherries to long distance markets such as Hong Kong and Taiwan. In the last few years different box liners have become available to the cherry industry; however, to our knowledge few evaluations have been done comparing them in similar conditions. In our California industry the use of solid box liners is becoming fashionable to keep green stems. In some cases, MAP box liners are being used upon customer demand.

The objectives of this research were to evaluate the effectiveness of MAP box liners on cherry storage/shipment potential, and to evaluate the solid box liner performance.

### Materials and Methods

'Bing' cherries were packed in 17.6 pound corrugated cartons using different box liners. In this test, solid and perforated box liners were compared with three alternative MAP box liners (LifeSpan, FRESHBAG, and MAP 012). The three MAP box liners were hermetically sealed by hand. After packaging and cooling, boxes were transported in an unrefrigerated truck to the F. Gordon Mitchell Postharvest Laboratory at the Kearney Agricultural Center. Cherries were stored for 45 days at 34°F for quality evaluations. Quality evaluations were carried out every 15 days within the 45 day period immediately after storage and followed by 4 days at 68°F.

*Quality Evaluations:* Quality attributes measured included soluble solids concentration (SSC), firmness (F), titratable acidity (TA), pH, skin color, and decay incidence. SSC, pH, and TA were measured on juice extracted with a food press and filtered through cheesecloth. SSC was measured with a temperature compensated handheld refractometer previously calibrated with distilled water. TA was measured by adding 5 g of sample juice to 50 mL of distilled water and titrating with 0.1 N sodium hydroxide (NaOH) to an end point of pH 8.2. TA is expressed as percent of malic acid, which is the predominant acid in this species. Average color was evaluated according to the *Commission Internationale de l'Eclairage* (CIE), with a Minolta colorimeter (Minolta, CR-200, Japan). Cherry skin color is expressed as hue angle (h°). The hue angle is expressed in degrees and is a measure of color that, for example, from 0° to 90° spans from red (dark mahogany) to orange to yellow. Darkening of cherries is an expression of fruit deterioration. Firmness was measured using a UC firmness tester with a 3 mm tip. Skin from opposite cheeks of each fruit was removed and

firmness calculated as the average of two measurements per fruit expressed as grams.

Stem browning, pitting, and decay incidence were also evaluated after 15, 30 and 45 days storage at 34°F followed by a 4 day warming period at 68°F. A total of 30 cherries was used to characterize individual fruit firmness and stem browning. Stem browning incidence was expressed as a percentage of stems showing visible browning. Cherries were segregated as pitted when pitting damaged areas were  $\geq 7$  mm diameter. After the four days warming at 68°F, 15 pounds of fruit per replication were used to determine the decay incidence expressed as percent by weight.

A completely randomized design with ten (boxes) replicates was used to evaluate quality attributes. Thus, ten boxes per each replicate were examined on each evaluation date. Data were subjected to analysis of variance and correlation analysis. Means were separated using LSD means separation at the 5% or 1% level using the SAS statistical software (SAS Institute, Cary, NC).

## Results

The LifeSpan, MAP 012, and FRESHBAG altered the CO<sub>2</sub> and O<sub>2</sub> concentrations around the fruit inside the boxes. The O<sub>2</sub> concentration inside the MAP 012 box liner was 15.0%, 9.6% and 8.6% after 15, 30 and 45 days of storage, respectively. By 15 days of cold storage, the highest CO<sub>2</sub> concentration was obtained on cherries packed using the LifeSpan and FRESHBAG box liners. The CO<sub>2</sub> concentration increased to 8-10% by the first 15 days reaching a plateau for the rest of the storage period. The oxygen concentration (3-5%) was also similar on cherries packed in these two types of box liners. Cherries packed using the MAP 012 reached a CO<sub>2</sub> concentration similar to the other two MAP box liners but after 30 days storage. CO<sub>2</sub> concentration inside the solid box liner increased to 3.5% by 15 days of storage, reaching a plateau of 4% CO<sub>2</sub> until the end of

45 days of storage. During this 45 day storage period, O<sub>2</sub> concentrations inside this solid box liner varied from 21% to 15%. CO<sub>2</sub> and O<sub>2</sub> concentrations inside boxes packed using the perforated box liners were not modified during this 45 days cold storage.

Decay was not observed immediately after 30 days of cold storage; however, after 45 days of cold storage decay became visible immediately upon removal. By 45 days of cold storage, cherries packed using the FRESHBAG, MAP 012 and LifeSpan had 0.2%, 1.1% and 1.5% decay while cherries packed with the solid box liner had 7.7% and in the perforated box liners had 20.6%. By 15 days of cold storage followed by 4 days at 68°F, decay incidence of 4.9%, 7.5%, 10.8%, 11.3%, and 29.4% was detected in cherries packed using the FRESHBAG, LifeSpan, solid box liner, MAP 012, and perforated box liner, respectively. By 30 days of cold storage followed by 4 days at 68°F, decay incidence of 23.5%, 25.3%, 25.8%, 31.1%, and 40.4% was detected in cherries packed using the FRESHBAG, MAP 012, LifeSpan, solid and perforated box liners, respectively. By 45 days of cold storage followed by 4 days at 68°F, decay incidence of 22.6%, 27.5%, 28.7%, 28.6%, and 40.1% was detected in cherries packed using the FRESHBAG, LifeSpan, MAP 012, solid and perforated box liners, respectively (Fig. 1). In all of the evaluations after the display period, decay incidence was significantly lower in the fruit packed with MAP than fruit packed with solid or perforated box liners.

MAP effectiveness on decay control was related to the concentration of CO<sub>2</sub> and O<sub>2</sub> reaching the steady state (plateau). LifeSpan and FRESHBAG box liners attained the highest CO<sub>2</sub> and the lowest O<sub>2</sub> concentrations. The CO<sub>2</sub>/O<sub>2</sub> relationship for LifeSpan was 8%/5% and 10%/5% in the case of FRESHBAG box liners.

*Stem Browning:* Stem condition was not affected after 45 days of cold storage.

However, stem quality losses began to be observed after 30 days cold storage during the warming period at 68°F. Cherry stem browning development after cold storage and the 68°F warming period was significantly delayed with all of the MAP box liners although there were no significant differences in stem browning condition between the three MAP treatments. The high CO<sub>2</sub> and low O<sub>2</sub> attained by the MAP box liners did not influence stem browning within this 45 day period followed by 4 days at 68°F. By 30 days followed by 4 days at 68°F, the severity of stem browning was 45% for fruit packed in solid and perforated box liners and only 30% for the fruit stored with MAP box liners. By 45 days followed by 4 days at 68°F, the severity of stem browning was 66% for the fruit packed in solid and perforated box liners and only 40% for the fruit stored with MAP box liners (Fig. 1).

Cherry firmness decreased from 238 g to approximately 193 g by 45 days of cold storage (Fig. 2). During the 45 day storage period, fruit packed using the MAP 012 had the highest firmness value (approximately 223 g). By 45 days of cold storage, cherries packed using the FRESHBAG or MAP 012 had the highest firmness. The firmness of fruit packed with these box liners was 210 g and 223 g respectively compared with 190 g for fruit packed in perforated or solid box liners.

Cherry pitting was visible early during cold storage in all of the treatments. Pitting incidence was very high in all of the treatments. However, its development was delayed by the MAP treatments. After 30 days pitting incidence was the same in all of the treatments.

Mahogany color 'Bing' cherries packed using the solid and perforated box liners darkened faster than mahogany color 'Bing' cherries packed using any of the MAP box liners. Hue measurements of 'Bing' cherries stored in solid box liners increased from 32° at harvest to 50° during the 45 day storage period, while cherries packed in any of the three MAP treatments

ended with a hue of 45° after the 45 day cold storage (Fig. 2). Cherries packed in the perforated box liner treatment had the darkest mahogany fruit color with a 53° hue value.

'Bing' cherry titratable acidity (TA) was lost during storage at 34°F. By 45 days of cold storage, TA decreased from 0.97% at harvest to 0.67% in cherries packed in the perforated box liner. Cherries packed in the solid box liner had 0.63% while cherries packed in any of the MAP box liners ended with 0.70% after 45 days cold storage (Fig. 2).

### Conclusions

The use of solid and perforated box liners did not protect cherries from deterioration as well as the MAP box liners. Cherries packed in perforated box liners had the fastest deterioration rate, thus, the shortest market life.

In a short-term shipment (within 15 days cold storage), cherries packed in the FRESHBAG had the lowest decay (4.9%), followed by cherries packed using the solid (10.8%) and LifeSpan (7.5%) box liners. However, the use of the solid box liner protected cherries from stem browning, skin color darkness, and firmness losses as well as any of the MAP treatments.

In a long-term shipment (longer than 15 days cold storage), the use of solid box liners did not protect cherries from decay development and other deterioration factors as well as any of the MAP treatments. MAP treatments delayed causes of 'Bing' cherry deterioration such as decay, stem browning, skin color darkness, firmness losses and TA degradation during storage (simulated shipment). Most of these beneficial effects were also carried over during the warming period at 68°F (simulated shelf life).

Market life extension was accomplished best using either FRESHBAG or LifeSpan box liners. Skin color darkening and stem browning were equally reduced by any of the

three MAP treatments (LifeSpan, FRESHBAG or MAP 012). FRESHBAG and LifeSpan reduced decay during cold storage and the effectiveness remained during shelf life. There were no differences in quality protection between these two MAP box liners.

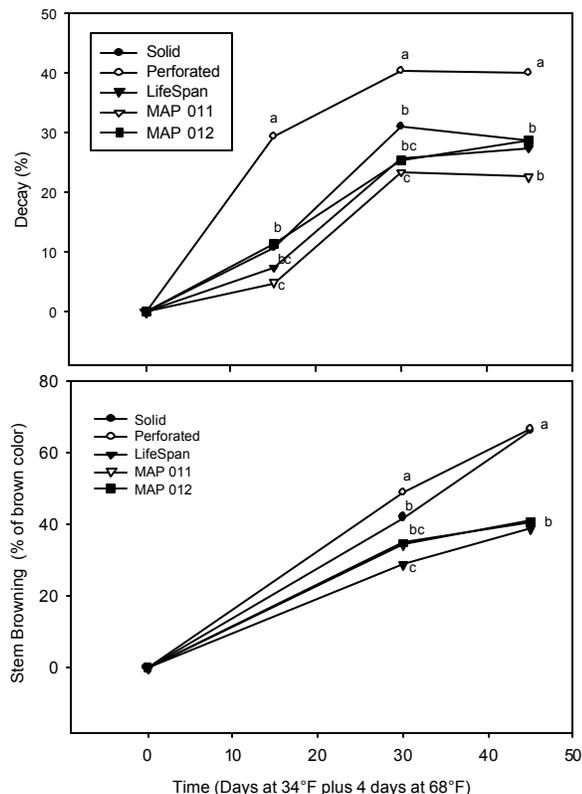


Figure 1. Decay and stem browning of 'Bing' cherries packed with different box liners stored for 45 days at 34°F plus 4 days at 68°F.

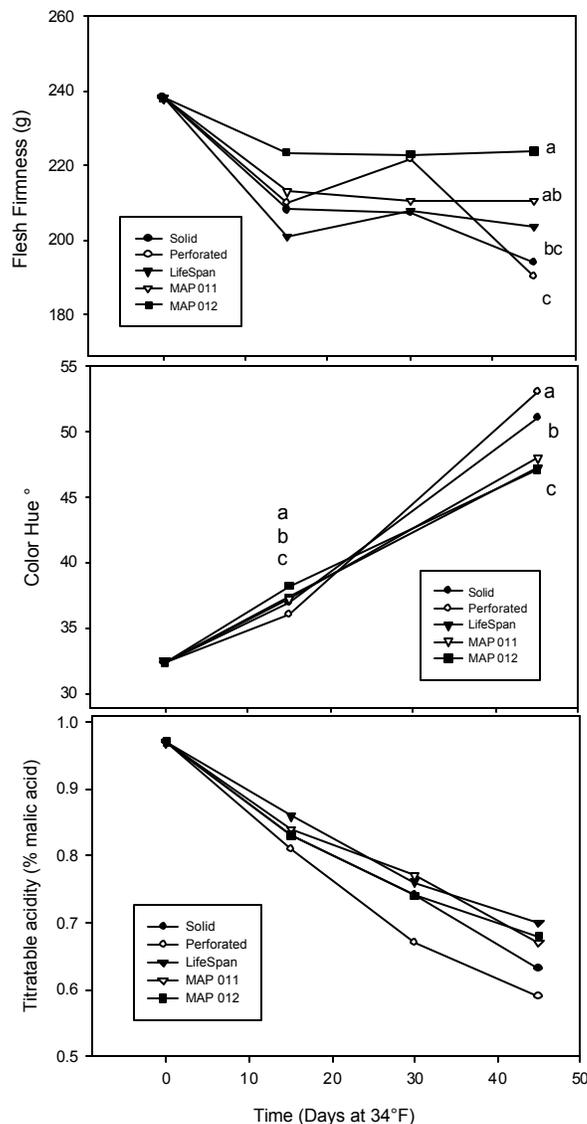


Figure 2. Firmness, color and titratable acidity of 'Bing' cherries packed with different box liners and stored for 45 days at 34°F.

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## EVALUATION OF OZONE GAS PENETRATION THROUGH CITRUS COMMERCIAL PACKAGES AND CONTROL OF GREEN AND BLUE MOLDS SPORULATION DURING COLD STORAGE

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Monir Mansour, Carlos H. Crisosto,  
and Thomas J. Clark

### Introduction

In recent work we reported the ability of gaseous ozone continuously released at low doses (0.3 or 1 ppm, v/v) to inhibit the sporulation of several important postharvest pathogens of table grapes, stone fruit, and citrus fruit (Palou et al., 2001a, 2001b, 2002).

Sporulation of *Penicillium digitatum* and *P. italicum* on cold-stored oranges or lemons was suppressed without injuring the fruit. In those trials, however, exposure of the fruit to the gas was unimpeded and we did not evaluate the effectiveness of ozone applied to commercially-packed citrus fruit.

The objectives of this work were to test the ability of ozone gas to penetrate into different commercial citrus fruit packages and to evaluate the effectiveness of the gas in controlling sporulation on commercially-packed citrus fruit.

### **Materials and methods**

**Fruit inoculation.** Lane late navel oranges (*Citrus sinensis* (L.) Osbeck) from commercial orchards in the San Joaquin Valley (California), were used in the experiments before any commercial postharvest treatments were applied. *P. digitatum* and *P. italicum* were grown on PDA in petri dishes at 25°C for 7 to 10 days. Spores were rubbed from the agar surface and a high-density spore suspension (approximately  $10^6$  spores ml<sup>-1</sup>) was prepared. Oranges were inoculated 1-cm deep into the flesh in the equator of two opposite faces with a

plastic syringe with a 20-mm needle. Approximately 0.25 ml of the spore suspension was applied at each inoculation point.

**Fruit packaging.** The following types of packages were prepared separately with fruit inoculated with each pathogen. See Table 1 for characteristics of each package.

Table 1. Characteristics of the different packages used in the experiments.

Package	Dimensions (inches) (long x wide x tall)	Volume (in <sup>3</sup> )	Lid	Box vented area (%)
Carton	17.3 x 11.9 x 11.7	2,408.7	Yes	2.6
RPC	23.5 x 15.5 x 10.1	3,678.9	No	35.9
Master carton	19.5 x 13 x 14.5	3,675.7	Yes	2.9
Plastic bag	21 x 10.5	-	-	0.7

- 1) Carton (naked): standard corrugated fiberboard citrus cartons with vents were filled with 60-70 oranges. Inoculated fruit were placed in the four corners and at the center of the carton at both the bottom and top levels of the carton. Ten inoculated oranges per carton were used. Cartons were stored with the lids on.
- 2) RPC (naked): returnable plastic boxes were filled with approximately 50 oranges. Inoculated fruit were placed in the four corners and at the center of the box at both the bottom and top levels of the box. Ten inoculated oranges per box were used.
- 3) RPC (bagged): 5 lb polyethylene bags with small vents were filled with oranges, 4 were inoculated and 10 were not inoculated. Eight bags were placed in each RPC.
- 4) Master carton (bagged): polyethylene bags were filled with inoculated and

non-inoculated oranges as previously described and placed in Master cartons. Ten bags were placed in each carton. Cartons were stored with the lids on.

Six packages of each type were prepared with fruit inoculated with *P. digitatum* and six with fruit inoculated with *P. italicum*. Master cartons were only prepared with fruit inoculated with *P. italicum*. For each pathogen, three of these six packages (replicates) were randomly stacked on one pallet and the other three on another pallet. Packed fruit was held at  $55 \pm 2^\circ\text{F}$  for 24 h before ozone exposure.

**Continuous exposure to gaseous ozone.** A water-cooled corona discharge ozone generator (Model Genesis CD-25G, Del Industries, San Luis Obispo, CA) was installed in an adjacent non-ozonated room and set to produce  $2.5 \text{ g h}^{-1}$  ozone. The gas was continuously released to a  $23,940 \text{ ft}^3$  cold storage room with a constant temperature of  $55 \pm 2^\circ\text{F}$  ( $12.8 \pm 1^\circ\text{C}$ ) through a 0.2-inch diameter Teflon tube anchored to the wall of the room. The room was aerated through 105 ceiling cones (with a 6 inch outlet) spaced 5 ft from each other. About 24 h after inoculation and packaging, the pallet containing one half of the packed fruit was stored in this room for 13 days. The pallet containing the other half of the packed fruit was stored at the same temperature and for the same time in an identical non-ozonated room (air atmosphere, control room).

The ozone concentration in the room and inside some of the packages on the pallet was continuously monitored by a 6-channel UV absorption ozone analyzer (Model 450 Nema, API Inc., San Diego, CA) with a minimum detection limit of 0.001 ppm. Air from the sampling points in the ozonated room was pumped through 0.15 inch internal diameter tubes to the analyzer, which was located in the adjacent room near the generator. The sampling points are specified in Table 2.

**Sporulation assessment.** Green and blue mold sporulation on Lane late navel oranges packed and stored in both ozonated and control rooms were recorded for each inoculated fruit after 13 days of storage at  $55^\circ\text{F}$ . A sporulation index was used where numbers 0, 0.5, 1, 2, 3, 4, and 5, respectively, indicated soft lesion but no spores or mycelium present, mycelium but no spores present, < 5%, 6 to 30%, 31 to 60%, 61 to 90%, and > 91% of the fruit surface covered with spores.

**Statistical analysis.** Scores in the sporulation index were considered as a quantitative variable. Each value in the data set was transformed to the square root of the value plus 0.5. An analysis of variance was applied to the transformed data and means were separated by Fisher's Protected Least Significant Difference test (LSD,  $P = 0.05$ ).

### Results and discussion

Average levels of the ozone concentration for the entire storage period are given for each sample point (Table 2) and type of package (Table 3). Ozone penetration in each type of package, calculated as a percentage of the ozone concentration in the room ambient, is also presented (Table 3).

Table 2. Average ozone levels for the entire storage period at the different sampling points.

Analyzer channel	Sampling point	Position in the pallet	Ozone levels (ppm, v/v)
Channel 1	Inside a plastic bag in a RPC box	Middle	0.12
Channel 2	Inside a RPC box (naked fruit)	Middle	0.59
Channel 3	Inside a carton (naked fruit)	Middle	0.03
Channel 4	Inside a plastic bag in a Master carton	Middle	0.07
Channel 5	Inside a carton (naked fruit)	Top	0.11
Channel 6	In the room ambient	-	0.72

A comparison between ozone concentrations inside the different packages indicated that the gas penetrated more easily into RPC boxes than into cartons or Master cartons. Nevertheless, ozone concentration in RPC boxes was significantly higher in the spaces surrounding the naked fruit than inside plastic bags (Table 3).

**Table 3.** Average ozone levels and percentage of ozone penetration (based on the average level in the room) for the entire storage period inside the different types of packages.

Packaging system	Ozone levels (ppm, v/v)	Ozone penetration (%)
Carton (naked)	0.07	9.7
RPC (naked)	0.59	81.9
RPC (bagged)	0.12	16.7
Master (bagged)	0.07	9.7

Ozone penetration was related to the vented area of each package (Table 1), indicating that the gas was not able to go through corrugated fiberboard carton or polyethylene bags. Ozone penetration was acceptable only in RPC boxes with naked fruit (82%, Table 3). On the other hand, the position of the box on the pallet also influenced the ozone concentration; ozone levels inside a mid-placed carton were in general lower than inside a top-placed carton (channel 3 vs. channel 5, Table 2).

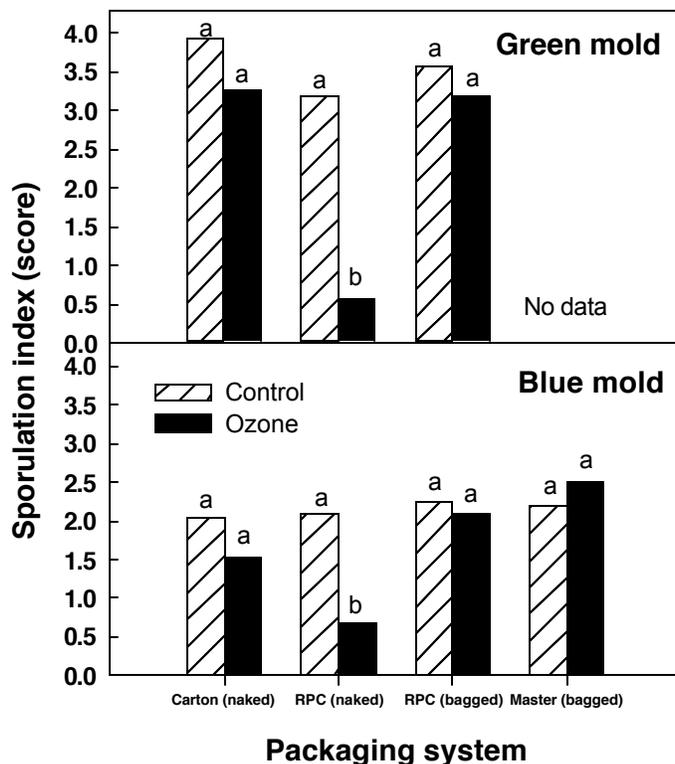
Sporulation of both *P. digitatum* and *P. italicum* was significantly inhibited by ozone exposure on oranges packed naked in RPC boxes, but it was not on oranges packed following the other packaging methods (Fig. 1). According to the percentages of ozone penetration inside the packages (Table 3), this result confirmed the need for good penetration and full contact to the decayed area on the fruit for ozone gas to be effective in controlling sporulation.

## Conclusions

- Gaseous ozone continuously generated in a cold storage room at rates ranging 0.5 to 1 ppm (v/v) effectively penetrated and controlled sporulation of both *P. digitatum* and *P. italicum* on oranges packed naked in RPC boxes.
- The gas was not able to penetrate properly through corrugated fiberboard carton or polyethylene bags. Therefore, it was not able to control sporulation on oranges packed in standard cartons, Master cartons, or plastic bags. Effective control of sporulation relied on actual physical contact between the gas and the decayed area of the fruit.

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**Fig. 1.** Sporulation index on Lane late oranges artificially inoculated with *Penicillium digitatum* or *P. italicum*, packed following different packaging systems, and stored at 55°F for 13 days in an air atmosphere (control) or in an ozonated atmosphere (0.5-1 ppm O<sub>3</sub> v/v). Within packaging systems, columns with the same letter are not significantly different according to Fisher's Protected LSD test ( $P < 0.05$ ) applied after an analysis of variance to the square root transformed data. Non-transformed means are shown.

## FUTURE EVENTS

### June 28, 2002

**Summer Variety Display / Research Update (Nutrient Deficiencies and Fertilizer Management) – 8:00 a.m., Kearney Agricultural Center, Parlier.**

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### July 26, 2002

**Summer Variety Display / Research Update (to be announced) – 8:00 a.m., Kearney Agricultural Center, Parlier.**

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