Fresh Nectarine Quality and Methyl Bromide Residues after In-package Quarantine Treatments

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Abstract. California nectarines [Prunus persica (L.) Batsch. var. nectarina (Ait) Maxim.] packed in single-layer corrugated fiberboard boxes were fumigated with methyl bromide (MB) at a rate of 48 g·m⁻³ for 21 hours at 21°C and normal atmospheric pressure and a 50% load (v/v) as a quarantine treatment for codling moth (Cydia pomonella L.). When the boxes were loosely stacked with spaces between them or tightly stacked and forced-air fumigated, concentration multiplied by time (C × T) relationships were > 68 g·m⁻³·h⁻¹, which is recommended for efficacy. Tightly stacked boxes that were not forced-air fumigated had C × T products < 68 g·m⁻³·h⁻¹. Organic bromide residues were < 0.001 µg·g⁻¹ and inorganic bromide residues were < 7.0 µg·g⁻¹ after 3 days. A trace to slightly phytotoxic response was observed in ‘Summer Grand’ and ‘Fantasia’ nectarines in 1989 but not in 1990.

The objectives of our investigations were to: 1) determine the sorption and desorption rates of MB from fumigated nectarines packed in corrugated fiberboard boxes; 2) measure MB residues in the nectarines; 3) evaluate the quality of the nectarines after their fumigation in corrugated fiberboard boxes; and 4) correlate data for objectives 1-3 with data for fumigation of fruit in field bins [i.e., data that were used to establish the quarantine treatment (Hartsell et al., 1992)].

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picked into bulk bins and transported by truck to the packinghouse. The noncooled fruit was mechanically dumped onto the grading table, washed, sprayed with food grade wax, mechanically sorted and sized, and packed in fiberboard boxes. No postharvest fungicides were applied.

All fruit were packed in corrugated fiberboard, bliss-style boxes (37.5 × 41.5 × 11.5 cm) designed for one layer of fruit. A thermo-formed, polyvinyl chloride tray with individual cups held from 25 to 32 pieces of fruit, which weighed ≈5 kg. Two pads filled with macerated paper were placed in each box for cushioning. Each side of each box had four rectangular ventilation slots (1.6 × 4.4 cm) that were covered with mesh screen with holes that were ≤1.6 mm in diameter to prevent insect infestation after packing and fumigation. The boxes were closed with hot-melt glue. All of these procedures, except for use of the screen, generally follow commercial practice.

Packed boxes of all cultivars tested in 1989 and of ‘May Grand’ in 1990 were loosely stacked, with spaces between the boxes, on a wood pallet, six boxes per layer, 11 layers high. Fourteen additional similarly packed boxes were then stacked on the floor of the chamber behind the pallet for a total of 80 boxes, the number required to occupy 50% load (v/v) within the 3.12-m3 fumigation chamber. There were 25.6 boxes/m3 containing ≈128 kg of fruit. This ratio compares to ≈179 kg·m−3 for nectarines fumigated in bulk bins (Hartsell et al., 1992). For the remaining cultivars during the 1990 season, the packed boxes in the chamber were kept tightly together on the pallet with four corner boards and two horizontal and two vertical straps. To improve the circulation of the MB under these tightly stacked conditions, two additional rectangular ventilation slots (1.6 × 4.4 cm) were cut into the end panels of the boxes packed with ‘Fantasia’. For three of the tests with ‘September Grand’, the boxes had the ventilation slots in the side increased to 3.2 × 4.4 cm.

The fruit, boxes, and pallet were fumigated with MB at a dose of 48 g·m−3 for 2 h at 21°C and normal atmospheric pressure. The chamber exceeded the positive-pressure certification required for tightness (U.S. Dept. Agriculture, 1976) and was equipped with a fan that circulated air at the rate of 5.72 m3·min−1 and that ran continuously during the exposure period. Sampling tubes to measure MB concentrations were placed inside the boxes at the top back, middle center, and bottom front of the chamber. One additional tube was placed in the air return duct. Temperature probes were inserted into the pulp of fruit that were located near the sampling tubes. Fruit temperatures were monitored during fumigation with a scanning tele-thermometer Model 47 (Yellow Springs Instrument, Yellow Springs, Ohio).

In another experiment with ‘September Grand’, which was replicated four times, the interior of the fumigation chamber was modified so that the boxes of fruit could be fumigated with forced-air (Fig. 1). Each box had four rectangular ventilation slots (1.6 × 4.4 cm) on each of two sides that were positioned 90° to the direction of the air/gas flow. Air pressure was measured with a U-tube manometer, and the sampling tube was located in the return air space. Three fumigations were conducted with air that circulated at the rate of 5.72 m3·min−1, with a negative pressure of 19.1 mm water, and one test was conducted with an air circulation rate of 2.60 m3·min−1, with a negative pressure of 9.6 mm water, or 233 × 10−6 m3·s−1 and 100 × 10−6 m3·s−1 of air, respectively, per kilogram of fruit.

Moisture content of the fiberboard boxes, taken with a Delmhorst moisture meter (model PA-1 Delmhorst Instrument, Boonton, N.J.), ranged from 7.5% to 8.5%. The wood pallets had a moisture content of 8%.

Concentrations of MB within the chambers were determined by a gas-liquid chromatograph (GLC) with a flame ionization detector. The gas samples were introduced into the GLC via an integral gas sampling valve with a 100-ml gas syringe, as described by Tebbets et al. (1983). Concentrations of MB in the chambers were determined ≈1 min after introduction of the chemical
and after 0.5, 1.0, and 2.0 h. Percent sorption was calculated from initial and final concentrations of MB in the chamber. Concentrations are presented as C × T products and expressed as grams per cubic meter per hour. The C × T products were calculated in a manner similar to that described by Monro (1969).

In preliminary tests, we found that empty boxes sorbed ≈35% more MB than empty bins (Hartsell et al., 1992) based on a 50% load (v/v) in the chamber. When boxes and bins were fully loaded with fruit, the bins with fruit sorbed ≈34% more MB than the boxes with fruit because fruit density was higher in the bins than in the boxes. The greater MB sorption by the box material was about equal to the MB sorption by the additional fruit in the bins. However, the boxes that were loosely stacked averaged 70.4 g·m⁻³·h⁻¹ ± 1.6 SD and was almost the same as that for the bins; 67.2 ± 2.1 (Fig. 2). The C × T values for boxes that were loosely stacked were 71.0, while those for boxes that were tightly stacked averaged only 49.0. The C × T products for boxes that were tightly stacked and had additional ventilation slots in the box ends or enlarged side vent holes averaged 69.0 and 66.0, respectively. The C × T products for the boxes that were forced-air fumigated at 5.72 or at 2.60 m³·min⁻¹ averaged 74.0 and 75.0, respectively. Yokoyama et al. (1990) proposed that a C × T product of 68.0 ± 3.0 g·m⁻³·h⁻¹ would be a useful measurement to maintain treatment security for control of codling moth eggs on all cultivars of nectarines. With the forced-air system, the MB concentration was reduced to 5 µg·g⁻¹ within 2.5 h, whereas 3.5 h was required by normal aeration. The lower C × T products found in the tight stacks were caused by slowed penetration of MB through the box vents, whereas those loosely stacked allowed MB access between the individual boxes. Tightly stacking the boxes with retaining straps and using forced-air fumigation eliminated the problem with slow MB penetration (Fig. 3).

After fumigation, the chamber and contents were aerated (forced air was used for the second test with 'September Grand') until MB concentrations in the return air duct were reduced to <5 µg·g⁻¹. Samples of the treated and control fruit were taken immediately after aeration and after 1, 3, 5, and 7 days of storage at 2.5C until levels decreased to 0.001 µg·g⁻¹. The gas-solid chromatography headspace method used for this analysis was described by Hartsell et al. (1992). Desorption rates of residual MB are expressed as log regression curves using the power curve: 

\[ y = ax^b \]

where \( x \) = time of analysis after 2 h aeration and \( y \) = residual value (µg·g⁻¹). Analysis of covariance (Dixon and Massey, 1969; Draper and Smith, 1981) was used to compare desorption rates between cultivars tested. An X-ray fluorescence spectrophotometer (Spectrace 431, Tracer Northern, Middleton, Wis.) was used for determining inorganic bromide residues in the fruit as described by Harvey et al. (1989).

Three sample boxes of nectarines from each fumigation test were inspected visually for MB injury as described by Harvey et al. (1982) and for other defects, such as bruising and cuts. These defects were rated on a scale of 0 = no injury to 5 = extensive injury. Firmness was measured at the equator of the fruit using a pressure tester with an 8-mm plunger. Soluble solids content (SSC) was measured by a refractometer.

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Inorganic bromide residues were well below the U.S. tolerance of 20 µg·g⁻¹. 'Summer Grand' had the highest (6.4 ± 0.4 µg·g⁻¹), 'Fantasia' the lowest (5.8 ± 0.5 µg·g⁻¹), and 'May Grand' was intermediate (6.2 ± 0.8 µg·g⁻¹). All controls contained <2 µg·g⁻¹ inorganic bromide. In addition,
mean residue values for all cultivars tested in boxes compared favorably with means of those treated in bins. 6.1 ± 0.6 and 6.3 ± 0.2 µg·g⁻¹ respectively.

The quality and condition of the nectarines after fumigation in boxes and 7 days of storage at 2.5°C were nearly the same as those of the control fruit. In 1989, when the fruit was hand sorted and sized, firmness ranged from 28 to 43 N, while SSC ranged from 9.9% to 11.4%. Incidence and severity of defects, such as bruising and cuts, were also similar. Differences in firmness, SSC, and defects between the fumigated and non-fumigated fruit were not significant.

‘May Grand’ was not damaged by MB, while ‘Summer Grand’ showed a trace of defects in 1989 but none in 1990. Bruising and cuts were more common in the control nectarines than in the fumigated nectarines. Differences in MB damage and other defects were not significant.

A major concern about fumigating fruit in packed boxes has been the high MB sorptive properties of fibrous materials. However, the density of packed fruit is less than that of bulk fruit, and C×T products for both were nearly the same. The fumigation treatment likely would be effective against codling moth as long as the boxes were loosely stacked with spaces between them in the fumigation chamber, or forced-air circulation was used during fumigation so that initial concentrations are sufficient to provide a C×T product that will maintain the security for control of codling moth.

Residues (organic and inorganic bromide) in nectarine cultivars fumigated in boxes were nearly equal to those in fruit from the bin tests and therefore do not exceed those allowed for export fruit.

California nectarines fumigated after being packed in fiberboard boxes showed no significant damage from MB and would be acceptable to the fresh fruit and vegetable trade. The ability to fumigate packed fruit selected for export would reduce a shipper’s costs because only fruit destined for countries that have a quarantine against codling moth would need to be fumigated. Fruit not needing fumigation could continue to be handled by current commercial methods.

**Literature Cited**


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