Postharvest Hot-Water And Fungicide Treatments For Reduction Of Decay Of California Peaches, Plums, And Nectarines

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SUMMARY

In laboratory tests, 1.5-minute hot-water dips or 3-minute hot-water showers in 125° F. water reduced losses due to decay in 5 varieties of nectarines by 65 to 75 percent compared to the untreated checks.

Treatments that combined fungicides with hot water were more effective than unheated fungicide treatments. The average percent of decay in peaches and nectarines dipped for 0.5 minutes in 125° F. water containing 225 p.p.m. 2,6-dichloro-4-nitroaniline (Botran) was 9.1 percent compared to 41.8 percent in the untreated check lots. A 0.5-minute hot-captan (150 p.p.m.) dip or a 1.5-minute hot-water dip was equally effective. In a comparison of the performance of various fungicides, methyl 1-(butylcarbamoyl)-2-benzimidazolecarbamate (benomyl) treatments resulted in the lowest level of decay.

In peaches sampled during the 1969 season, a 1.5-minute, 125° F. hot-water immersion treatment in a commercial packing shed reduced losses due to postharvest decays by approximately 74 percent. A commercial hot-Botran treatment was also effective in controlling decay.

The average percent of decay in peaches commercially treated for 0.5 minutes in 125° F. water containing ¼ to ⅜ lb. Botran 75W per 100 gallons was 5.7 percent compared to 27.4 percent in the untreated check lots. Nectarine decay losses were similarly reduced by the treatment. Plums required 1-minute treatments in hot Botran for effective decay control. Some fruit of the peach varieties Fay Elberta and Duke's Pride and the plum variety Kelsey were injured by commercial handling following hot-Botran treatments.

Commercial hot-water, hot-Botran, and wax-fungicide applications were equally effective in controlling decay on peaches and nectarines.

BACKGROUND

Brown rot, caused by *Monilinia fructicola* (Wint.) Honey, and Rhizopus rot, caused by *Rhizopus stolonifer* (Ehr. ex Fr.) Lind, are the chief postharvest diseases of peaches, plums, and nectarines. Black-mold rot (*Aspergillus niger* v. Teigh) and blue-mold rot (*Penicillium* sp.) also occur but are of less importance (*8*).[2]

Brown rot of peaches, plums, and nectarines has become a serious problem during the past few years in California, particularly on varieties that mature during the second half of the harvest season. Past occurrences of the disease

[1] Fresno, Calif.

[2] Italic numbers in parentheses refer to Literature Cited, page 12.

had been associated with periods of rainfall or unusually humid growing conditions, but the disease now appears seasonally in all growing areas of the State. Most postharvest decays of stone fruits develop when the fruit is transferred to ripening temperatures following storage and shipment. Thus, fruit that is of acceptable quality at shipping point may develop rot when ripened at destination.

In 1963 decay losses in California peaches and nectarines were estimated at 2 percent of the total crop, representing a monetary value of $1,225,800 (*1*). Losses for the more recent years have been higher. During the second half of the 1968 growing season, nectarine growers and shippers estimated a market loss of $2,000,000 due to decay. One shipper's losses on one variety of nectarine alone was estimated at $62,500 (Personal communications).

Postharvest rots of peaches and nectarines have been reduced with fungicidal dips (*6*) and with fungicide-impregnated waxes (*4*) or wraps (*5*). Hot-water treatments also have effectively reduced decay of eastern-grown varieties of peach and nectarine (*9*). Wells and Harvey (*10*) tested hot-water treatments with western-grown varieties and found that decay of naturally infected fruit was reduced from an average of 65 percent in untreated lots to 17 percent in lots treated for 1.5 minutes in 125° F. water. Equivalent control was obtained with a 30-second treatment in 125° F. water containing 225 parts per million (p.p.m.) of 2,6-dichloro-4-nitroaniline (¼ lb. Botran 75W per 100 gallons of water).

Further work, summarized in this report, has been necessary to evaluate the performance of heat treatments under actual commercial conditions, and in combination with other fungicides. In addition, evaluations were needed of other methods of heat-treating fruit, such as moisture-saturated air or hot-flood showers. The performance of commercial heat treatments for peaches and nectarines also needed to be compared with fungicide-impregnated wax emulsions, which are used in some sheds.

MATERIALS AND METHODS

Freshly harvested fruit were obtained from local orchards or packing sheds, and were selected for uniform maturity and for the absence of injury or decay. Peaches were brushed prior to selection. The number of fruit per treatment varied with each experiment depending on fruit size and the scale of the test. In laboratory experiments sample sizes generally ranged between 40 and 60 fruit, with some as high as 120. Larger sample sizes, ranging from 120 to 180 fruit, were used for the commercial treatments. Experiments were replicated at least 4 times, each time with a different variety of fruit.

Fruit was treated with hot air in a chamber with moisture-saturated air at a preset temperature of ±1° F., and with a continuous flow rate of 500 to 600 cubic feet of air per minute. Treatments were 8 to 10 minutes at 125°, and 25 to 30 minutes at 110° F.

Hot water was tested both as a dip and as a shower treatment. Fruits were placed in a basket and immersed in an insulated stainless-steel tank of 100 gallons capacity. Water was circulated by pump at 100 gallons per minute. The temperature was maintained at set point ±0.5° F. with electric heating coils activated by a temperature controller with a thermistor probe. Shower treatments were conducted in a chamber equipped with a flood screen that maintained an even shower of hot water over the fruits at the rate of 15 gallons per minute per square foot chamber area. Temperature changes in the fruit during treatment were determined with wire thermocouple probes inserted 1, 10, and 20 mm. under the skin of the fruit, which had been precooled for 16 to 20 hours at 40° F.

Half-minute fungicidal dip treatments, in both heated and unheated water, were tested with the following materials: 2,6-Dichloro-4-nitroaniline (Botran 75W)[3], at 225 and 900 p.p.m. (¼ and 1 lb. per 100 gallons, respectively); captan 50W at 150 and 600 p.p.m. (¼ and 1 lb. per 100 gallons, respectively); 2-(4-

[3] The Upjohn Company, Kalamazoo, Mich.

thiazolyl) benzimidazole (Thiabendazole)[4], at 150 p.p.m. (active ingredients); methyl 1-butyl-carbamoyl-2-benzimidazolecarbamate (benomyl)[5], at 150 p.p.m. (active ingredients); and 5-aceto-8-hydroxyquinoline sulfate (G-20072)[6], at 150 p.p.m. (active ingredients).

In a separate test, comparisons were made of Thiabendazole, benomyl, and *a*-2,4-dichlorophenyl - *a* - phenyl-5 - pyrimidinemethanol (EL-273)[7], at 50 p.p.m.

The performance of a commercial hot-water treatment was tested with a 1,500-gallon tank in a local packing shed. Water was circulated through heat-exchange coils of a boiler, which maintained temperatures at 125° ±2° F. Treatment times of 1.5 minutes were controlled with a variable-speed, submerged conveyor belt. Fruit entering the shed was first washed in a detergent spray, after which it was defuzzed with rotating brushes and a clean water spray. After treatment, the fruit was packed in lug boxes with slatted sides and hydrocooled for 25 minutes in 35° water containing 1 to 3 p.p.m. chlorine.

A half-minute postharvest heat treatment for peaches and nectarines was tested in a second commercial shed equipped with a 600-gallon tank. Water was heated to 125° F. by circulation through a boiler, and 1/4 to 3/8 lb. Botran 75W per 100 gallons was added. Plums were treated for 0.5 and 1 minute. Fruit samples for decay studies were taken from the conveyor belts before the heat treatment, immediately after treatment, and after the fruit had been graded and commercially packed for shipment.

A 17-second treatment for peaches and nectarines was tested in a third packing shed using a similar hot-Botran dipping tank.

Wax applications were treated in commercial units at packing sheds. A wax emulsion mixed with orthophenylphenate and Botran was applied as a mist spray during brushing.

The relative degree of decay control provided by the various postharvest treatments was determined by dividing a given lot of fruit into subsamples, each of which received a different treatment. The subsamples were introduced into the commercial conveyor systems immediately before the treatment and were recovered immediately afterwards.

Treated fruits were packed in commercial peach lugs with plastic trays, were stored for 5 to 7 days at 35° F. and ripened for 3 to 4 days at 70°, after which they were examined for decay or injury. Fruit was considered decayed if *Monilinia, Rhizopus, Penicillium,* or *Aspergillus* rot was present at any stage of development.

Weight loss determinations were made on samples of 10 fruit treated with hot water or the hot fungicidal dips. Weights were taken after 0, 3, and 6 days of storage at 70° F. and at 75 to 90 percent relative humidity. Losses were expressed as average percents of the initial weights.

Botran residues on peaches, nectarines, and plums were determined by the method of Cheng and Kilgore (*3*) with a gas chromatograph equipped with an electron-capture detector.

Data were evaluated by analysis of variance and Duncan's Multiple Range Test. Differences were considered significant at the 5-percent level.

RESULTS

Comparison of Hot-Air, Hot-Water Dip, and Hot-Water Shower Treatments—Laboratory Tests

Five varieties of nectarine were treated with hot air, hot-water dips, and hot-water showers to determine the relative effectiveness of the methods of heating fruit to control postharvest decays. In preliminary tests, hot-air treatments of 110° F. for 30 minutes or 125° for 10 minutes caused slight, but noticeable, injury to the fruit. Consequently, treatments at 125° were limited to 8 minutes and those at 110° to 25 minutes.

An average of 36.3 percent of decay developed in the untreated fruit (table 1). The average percent of decay in fruit dipped for 1.5 minutes in hot water, or treated for 3 minutes in a hot shower, were 7.8 and 11.1 percent, respectively,

[4] Merck & Co., Rahway, N. J.
[5] E. I. du Pont de Nemours & Co., Wilmington, Del.
[6] Geigy Chemical Corp., Ardsley, N. Y.
[7] Eli Lilly & Co., Indianapolis, Ind.

TABLE 1.—*Percent decay on five varieties of nectarines heated by hot air, hot-water dips, and hot-water showers; fruit held for 5 to 7 days at 35° F. and 4 days at 70° F.*

Treatment			Percent decay in indicated variety [1]					
Heat application	Temperature	Exposure	Red Grand	Sun Grand	Late Le Grand	Regal Grand	Sept. Grand	Average [2]
	°F.	*Min.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Hot air	110	25	1.7	13.3	6.0	42.5	23.3	17.3 ab
Hot air	125	8	8.3	13.3	38.0	25.0	35.0	23.9 bc
Hot-water dip	125	1.5	0	6.7	14.0	10.0	8.3	7.8 a
Hot-water shower	125	1.5	8.3	8.3	28.0	20.0	18.4	16.6 ab
Hot-water shower	125	3	10.0	6.6	12.0	13.3	3.3	11.1 ab
Dry check			16.7	15.0	54.0	75.0	26.7	36.3 c

[1] Percent decay in lots of 60 fruit per treatment for the varieties Red Grand, Sun Grand, and Regal Grand; 50 fruit per treatment for Late Le Grand; and 40 fruit per treatment for September Grand.

[2] Figures not followed by the same letter are significantly different at the 5-percent level.

representing 65 to 75 percent reductions from the decay level in the untreated check lots. Fruit treated for 1.5 minutes in the hot-water shower developed 16.6 percent decay, somewhat more than that from the 3-minute treatments, but significantly less than that in the untreated checks. Decay was also significantly less in fruit treated with hot air at 110° F. for 25 minutes (17.3 percent) than in the checks, but no significant reduction occurred in lots treated at 125° for 8 minutes (23.9 percent).

Initial pulp temperatures of precooled fruit were 60°, 57° and 48° F. at 1, 10, and 20 mm. under the skin surface, respectively. Corresponding temperatures after a 25-minute treatment in 110° air were 106°, 95°, and 89°, respectively; and after 1.5 minutes in a 125° water dip, 113°, 78.5°, and 52°. Three-minute hot-shower treatments resulted in temperature changes similar to those from the 1.5-minute hot-dip treatment.

Evaluation of Combination Hot-Water and Fungicide Treatments—Laboratory Tests

Botran and captan dips and showers.—Treatments that combined the use of hot water and fungicides were significantly more effective than the corresponding unheated fungicide treatment alone (table 2). The average percent decay of fruit dipped for 0.5 minutes in 125° F. water containing 225 p.p.m. of Botran was 9.1 percent compared to 41.8 percent decay in the untreated check lots. The unheated Botran (225 p.p.m.) treatment had no significant effect on the level of decay. The hot-captan treatment reduced decay to 8.3 percent, thus was as effective as the hot-Botran dip. The unheated captan treatment resulted in 26.0 percent decay, significantly better than in the unheated Botran treatment. A 1.5-minute hot-water treatment reduced decay to 6.0 percent, performing as well as the 0.5-minute hot-fungicide treatments.

Hot-fungicide shower treatments required longer exposure times than the corresponding dip treatments for comparable decay control. The average percent of decay in lots treated with a 1.5-minute hot-captan shower was 7.8 percent compared to 8.3 percent in lots treated with a 0.5-minute hot-captan dip.

Botran, captan, benomyl, Thiabendazole, and Geigy-20072 dips—As unheated fungicidal dip treatments, all the materials, except Botran at 225 p.p.m., reduced decay significantly below that of the untreated check lots (table 3). The average percent of decay in treated lots ranged from 16.8 to 48.0 percent, compared to 67.8 percent in the checks. The benomyl dip treatment resulted in the lowest incidence of decay (16.8 percent) in the unheated lots. Of the remaining fungicides, Geigy-20072 at 150 p.p.m. reduced decay to 38.9 percent and thus was more effective than 900 p.p.m. Botran (48.0 percent decay), but not significantly different from 600 p.p.m. captan (39.8 percent decay) or Thiabendazole (43.2 percent decay).

The performance of the experimental materials was significantly improved when used in combination with hot water, as was the case

TABLE 2.—*Percent decay of peaches and nectarines treated with hot water, captan, and Botran; fruit held 7 days at 35° F. and 4 days at 70° F.*

Treatment				Percent decay in indicated variety [1]					
				Nectarines				Peach	
Type of treatment	Fungicide concentration	Water temperature	Exposure	Early Sun Grand	Regular Sun Grand	Red Grand	Gold King	Fiesta	Average [2]
	P.p.m.	*°F.*	*Min.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Hot-water dip		125	1.5	11.7	13.3	1.6	3.3	0	6.0 a
Hot-water shower		125	1.5	17.5	18.3	1.6	16.7	2.4	11.3 ab
Hot-water shower		125	3.0	6.7	13.3	5.8	13.3	7.1	9.2 a
Hot-Botran dip	225	125	0.5	7.5	18.3	2.5	15.0	2.4	9.1 a
Hot-Botran shower	225	125	0.5	32.5	27.5	5.8	15.0	19.0	20.0 ab
Hot-Botran shower	225	125	1.5	12.5	19.2	4.2	8.3	4.8	9.8 a
Hot-captan dip	150	125	0.5	1.7	10.0	5.0	20.0	4.8	8.3 a
Hot-captan shower	150	125	1.5	6.7	10.0	2.5	15.0	4.8	7.8 a
Unheated-Botran dip	225	75	0.5	58.3	60.0	2.5	70.0	23.8	42.9 c
Unheated-captan dip	150	75	0.5	20.8	36.7	10.0	48.3	14.3	26.0 b
Dry check				55.0	89.2	5.8	40.0	19.0	41.8 c

[1] Percent decay in lots of 120 fruits per treatment for all nectarine varieties, and 84 fruits per treatment for the peach variety.
[2] Figures not followed by the same letter are significantly different at the 5-percent level.

TABLE 3.—*Percent decay on peaches and nectarines dipped for 1/2 minute in 75° or 125° F. fungicide suspensions; fruit held for 7 days at 35° F. and 5 days at 70° F.*

	Percent decay in indicated variety [1]				
	Nectarines			Peach	
Fungicide and temperature of application [2]	Gold King	Regal Grand	Sept. Grand	Fiesta	Average [3]
°F.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Botran, 75°	53.3	47.5	56.0	58.0	53.7 de
Botran (900 p.p.m.), 75° [4]	28.3	65.0	62.0	36.7	48.0 d
Botran, 125°	5.0	17.5	38.0	21.7	20.5 ab
Botran + Thiabendazole, 125°	3.3	2.5	24.0	11.7	10.4 ab
Botran + benomyl, 125°	0.0	0.0	14.0	0.0	3.5 a
Botran + G-20072, 125°	1.6	5.0	22.0	1.7	7.6 a
Captan, 75°	45.0	32.5	42.0	42.0	40.4 cd
Captan (600 p.p.m.), 75°	53.0	42.5	42.0	21.7	39.8 cd
Captan, 125°	5.0	10.0	34.0	20.0	17.2 ab
Captan + Thiabendazole, 125°	1.6	5.0	44.0	3.3	13.5 ab
Captan + benomyl, 125°	0.0	2.5	6.0	5.0	3.4 a
Captan + G-20072, 125°	5.0	7.5	36.0	15.0	15.8 ab
Thiabendazole, 75°	31.7	47.5	42.0	51.7	43.2 cd
Thiabendazole, 125°	15.0	10.0	30.0	5.0	15.0 ab
Benomyl, 75°	8.3	25.0	24.0	10.0	16.8 ab
Benomyl, 125°	0.0	0.0	16.0	1.7	4.4 a
G-20072, 75°	26.7	52.5	18.0	58.3	38.9 c
G-20072, 125°	3.3	20.0	38.0	11.7	18.3 ab
Water, 1.5 min, 125°	3.3	5.0	10.0	38.3	14.1 ab
Dry check	38.3	75.0	88.0	70.0	67.8 e

[1] Percent of 40 to 60 fruit per treatment.
[2] Unless otherwise noted, Botran was tested at 225 p.p.m. and the other fungicides at 150 p.p.m.
[3] Figures not followed by the same letter are significantly different at the 5-percent level.
[4] This treatment resulted in visible residue deposits on the fruit.

with Botran and captan. One-half-minute hot fungicidal dips were, in general, as effective as the 1.5-minute hot-water treatment. The average percent decay in lots treated with heated Thiabendazole, Geigy-20072, captan, and Botran ranged from 15.0 to 20.5 percent, compared to 14.1 percent in lots treated for 1.5 minutes in hot water. Heated benomyl treatments resulted in the lowest decay levels—4.4 percent in lots treated with benomyl alone, and 3.5 and 3.4 percent when used in combination with Botran or captan, respectively. In general, the effectiveness of the experimental materials was not significantly improved by Botran or captan supplements.

The 1.5-minute hot-water or 0.5-minute hot-fungicide treatments caused no apparent injury to the fruit. Weight-loss determinations were made with Fiesta peaches to detect injury that may not have been evident by visual observation. After 3 days at 70° F. and at 75 to 90 percent relative humidity, there were no significant differences in weight loss between the checks and any of the heat-treated lots (table 4). After 6 days, however, weight loss in lots treated 1.5 minutes in hot water was 8.5 percent; the loss in lots treated for 0.5 minute with heated Botran plus benomyl was 8.8 percent; and the loss in lots treated with heated captan plus benomyl was 9.1 percent, all significantly greater than in the untreated checks (7.0 percent). Half-minute heat treatments using any of the fungicides alone did not result in weight loss significantly greater than that in the checks.

TABLE 4.—*Percent weight loss, after 3 and 6 days at 70° F. and 75 to 90 percent relative humidity, of Fiesta peaches treated with hot water and hot fungicides*

Treatment [1]	Average weight loss [2]	
	3 days	6 days
	Pct.	*Pct.*
Dry check	4.4 a	7.0 a
Water (1.5 min)	4.7 a	8.5 b
Botran	4.6 a	8.0 ab
Captan	4.0 a	7.2 a
Benomyl	3.7 a	6.9 a
Thiabendazole	3.6 a	7.0 a
Geigy-20072	3.7 a	7.0 a
Benomyl + Botran	4.8 a	8.8 b
Benomyl + captan	4.0 a	9.1 b

[1] One-half-minute treatments, unless otherwise noted, in 125° F. water containing 225 p.p.m. Botran or 150 p.p.m. of other fungicides.

[2] Average percent loss from initial weights of 10 fruits sampled per treatment. Figures in each column not followed by the same letter are significantly different at the 5-percent level.

Benomyl, Thiabendazole, and EL–273 dips.— Benomyl, Thiabendazole, and EL–273 were tested at the relatively low concentration of 50 p.p.m. for activity against postharvest decay of Halloween peaches (table 5). All treatments, whether heated or unheated, significantly reduced decay compared to the unheated water dip or the dry checks. The average percent of decay in the unheated benomyl and EL–273 treatments were 35.8 and 22.5 percent, respectively, significantly lower than the Thiabendazole-treated lots.

Each of the three fungicides was more effective in combination with a 0.5-minute heat treatment than when unheated, and was as effective as the 1.5-minute hot-water treatment. The lowest decay values resulted from hot-benomyl (7.5 percent) and hot EL–273 (5.8 percent) treatments. These values, however, were not significantly different from those obtained from hot Thiabendazole or the 1.5-minute hot-water treatment (15.0 and 11.7 percent, respectively).

Commercial Hot-Water Treatments

A tank, providing a 1.5-minute, 125° F. hot-water immersion treatment, installed in a commercial packing shed, reduced losses due to postharvest decays in peaches sampled during the season by approximately 74 percent. The average percent of decay in lots defuzzed with a wet brush and directly packed without a heat treatment was 16.9 percent after a simulated marketing period, while corresponding heat-treated lots had 3.9 percent decay (table 6). The hot-water dip was also effective when the fruit was hydrocooled after treatment (7.4 percent). In untreated and hydrocooled fruit the average decay was 25.9 percent.

TABLE 5.—*Percent decay in Halloween peaches treated with hot water and hot fungicides; fruit was held 5 days at 35° F. and 3 days at 70° F.*

Treatment			Percent decay			
			Replication [2]			
Fungicide or heat application [1]	Fungicide concentration	Water temperature	1	2	3	Average [3]
	P.p.m.	*°F.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Water		125	30.0	32.5	45.0	35.8 b
Water (1.5 min)		125	15.0	12.5	7.5	11.7 a
Thiabendazole	50	125	7.5	15.0	22.5	15.0 a
Benomyl	50	125	2.5	7.5	12.5	7.5 a
EL-273	50	125	2.5	7.5	7.5	5.8 a
Thiabendazole	50	75	50.0	52.5	47.5	50.0 c
Benomyl	50	75	40.0	45.0	22.5	35.8 b
EL-273	50	75	20.0	32.5	15.0	22.5 b
Water		75	82.5	55.0	72.5	70.0 d
Dry check			65.0	85.0	77.5	75.8 d

[1] One-half-minute dip treatments, unless otherwise stated.
[2] 40 fruit per treatment per replication.
[3] Figures not followed by the same letter are significantly different at the 5-percent level.

TABLE 6.—*Percent decay of peaches sampled from a commercial packing shed after a hot-water and hydrocooling treatment; fruit held 7 days at 35° F. and 4 days at 70° F.*

			Percent decay in fruit			
Peach variety	Date packed in 1969	Fruit per treatment	Check	Hot-water dip [1]	Hot-water dip plus hydrocooling [2]	Hydro-cooling only
		No.	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Coronet	June 19	140	3.5	1.4	1.0	2.8
Coronet	June 20	120	6.7	0.0	3.3	31.6
Coronet	June 24	120	5.0	0.0	6.7	13.3
Coronet	June 25	120	5.8	3.3	2.5	14.2
Red Top	July 3	120	23.3	3.3	8.3	20.8
Regina	July 3	120	33.3	6.7	3.3	30.8
Suncrest	July 16	120	39.2	6.7	23.3	63.3
Late Suncrest	July 23	120	18.3	10.0	10.8	30.0
Average [3]			16.9 b	3.9 a	7.4 a	25.9 c

[1] 1.5 minutes in 125° F. water.
[2] 20 minutes in 37° F. water containing 1 to 3 p.p.m. chlorine.
[3] Figures not followed by the same letter are significantly different at the 5-percent level.

The hot-water treatments had no deleterious effect on the market quality of the peach varieties tested. No injury, shriveling, or premature ripening of the fruit was observed during a 6-day holding period at 70° F. at about 75 to 90 percent relative humidity (table 7). After 3 days' holding, the average weight loss in fruits that were defuzzed and heat-treated was 6.2 percent, compared to 6.1 percent in samples similarly defuzzed, but not heat-treated. After 6 days' holding, weight loss of the heat-treated fruit averaged 12.1 percent, slightly higher, but not significantly different from the 10.4 percent loss in the untreated checks. Significantly less weight was lost, however, if heat-treated fruit was subsequently hydrocooled in chlorinated water.

TABLE 7.—*Percent weight loss, after 6 days at 70° F. and 75 to 90 percent relative humidity, of peaches heat-treated and hydrocooled under commercial conditions*

Variety	Percent weight loss in indicated treatment [1]			
	Check	Hot-water treatment	Hot-water plus hydrocooling	Hydro-cooling only
	Pct.	*Pct.*	*Pct.*	*Pct.*
Coronet	9.2 [2]	10.9	7.4	8.3
Coronet	10.0	11.4	10.1	8.2
Suncrest	9.6	10.8	8.6	9.3
Late Suncrest	12.7	15.3	11.5	13.8
Average [3]	10.4 ab	12.1 b	9.4 a	9.9 a

[1] All fruit defuzzed with a wet brush. Heat treatments consist of a 1.5-minute dip in 125° F. water. Hydrocooling is for 20 minutes in water containing 1 to 3 p.p.m. chlorine.

[2] Average percent loss from initial weight of 10 fruit sampled per treatment.

[3] Figures not followed by the same letter are significantly different at the 5-percent level.

Commercial Hot-Botran Treatments

The average percent decay in peaches sampled from a packing shed using a hot-Botran treatment was reduced from 27.4 percent in untreated check lots to 5.7 percent in fruit treated for 0.5 minute in 125° F. water containing 1/4 to 3/8 lb. Botran per 100 gallons (table 8). Decay of fruit sampled immediately after treatment without commercial handling was 4.6 percent, not significantly different from the commercial lots. The overall reduction in decay on peach varieties treated in this unit throughout the season was 79 percent.

Heated-Botran treatments also were effective in reducing decay of nectarines. The 0.5-minute dip reduced losses on the two varieties tested from an average of 42.1 percent in the untreated samples to 12.8 percent in samples treated and then commercially packed.

The 0.5-minute hot-Botran treatment reduced decay in samples of Santa Rosa plums from 9.3 percent to 2.3 percent, but was less effective with the later varieties. Subsequent use of a 1-minute treatment with at least 3/8 lb. Botran per 100 gallons provided satisfactory control with the varieties Laroda, Late Santa Rosa, Nubiana, and Casselman. Overall reduction of plum decay throughout the season was about 62 percent.

The peach varieties Fay Elberta and Duke's Pride, and the plum variety Kelsey, sampled immediately after the hot-Botran treatments, developed no injury. However, about 20 percent of the samples that were commercially handled and packed after treatment developed brown surface injuries after several days in cold storage. The injuries resembled conveyor-belt abrasions.

The average weight loss from untreated fruit after 3 days at 70° F. and 75 to 90 percent relative humidity was 5.6 percent for peaches and 4.6 percent for nectarines (table 9). Weight loss from fruit treated with a 0.5-minute hot-Botran dip was not significantly different from that in the checks. Longer hot-Botran dips of 1 or 1.5 minutes duration resulted in average weight losses of 6.5 to 7.1 percent for peaches and 5.9 to 6.0 percent for nectarines—significantly greater than in the checks.

Plums lost relatively little weight during a 3-day examination period. Even after a 6-day examination period, there was no significant difference in weight loss between the treated (9.9 percent) and untreated (8.5 percent) samples.

Comparison of Commercial Hot-Water, Hot-Botran, and Wax-Fungicide Treatments

Three varieties of peach and four varieties of nectarine were treated in each of four packing sheds using different postharvest treatments. Thus, commercial hot-water treatments were compared directly with hot-Botran treatments, and with commercial wax-fungicide applications. Statistically, there were no significant differences in decay following the different postharvest treatments (table 10). The average percent decay in treated fruit ranged from 10.3 to 15.6 percent compared to an average of 44.9 percent decay in the untreated checks.

TABLE 8.—*Percent decay of peaches, plums, and nectarines treated with a heated (125° F.) Botran dip in a commercial packing shed; fruit held 7 days at 35° F. and 4 days at 70° F.*

Variety	Dates of sampling in 1969	Number of lots sampled [1]	Treatment: Exposure	Treatment: Botran concentration 75W	Percent decay in indicated treatment: Check	Hot-Botran dip	Hot-Botran dip plus commercial handling [2]
		No.	*Min.*	*Lb./100 gal.*	*Pct.*	*Pct.*	*Pct.*
Peaches:							
Coronet	June 14-27	6	0.5	¼	16.0	2.7	1.1
Suncrest	June 29-July 15	3	0.5	¼	37.5	4.8	3.9
Fay Elberta	July 19-22	2	0.5	¼	12.4	0.0	[3] 0.0
Elberta	July 23-Aug. 1	5	0.5	¼	32.7	3.5	9.3
Jody Gaye	Aug. 3-8	3	0.5	⅜	56.2	14.6	16.0
Rio Oso Gem	Aug. 5	1	0.5	⅜	78.9	10.5	25.7
Duke's Pride	Aug. 28-Sept. 10	5	0.5	⅜	8.3	2.3	[3] 1.1
Average [4]					27.4 b	4.6 a	5.7 a
Nectarines:							
Early Sun Grand	June 28	1	0.5	¼	3.0	0	7.0
Gold King	Aug. 16	1	0.5	⅜	81.3	23.9	18.7
Average [4]					42.1 b	11.9 a	12.8 a
Plums:							
Santa Rosa	June 14-27	7	0.5	¼	9.3	1.6	2.3
Rosa Grande	June 26-30	5	0.5	¼	10.9	8.4	6.0
Laroda	July 5-18	3	1.0	⅜	14.9	1.7	3.3
Late Santa Rosa	July 14-26	4	1.0	⅜	7.3	3.0	3.3
Nubiana	July 16	1	1.0	⅜	4.9	1.2	2.9
Kelsey	July 21-24	2	1.0	⅜	0.0	0.0	[3] 0.0
Casselman	Aug. 7-9	3	1.0	⅜	10.0	3.1	5.5
Average [4]					9.2 b	3.2 a	3.5 a

[1] Each lot averaged 145 plums or 108 peaches or nectarines per treatment.
[2] Movement on conveyor belts and manual packing operations.
[3] Brown scalded areas on approximately 20 percent of samples of this variety.
[4] Averages adjusted for number of lots sampled. Figures not followed by the same letter are significantly different at the 5-percent level.

Hot-water treatments of 1.5 minutes at 125° F. reduced decay to a mean of 15.6 percent. Decay reduction was only slightly improved when the treatment time was increased to 3 minutes (14.5 percent decay). One half-minute hot-Botran treatments performed as well as hot-water treatments, reducing decay to an average of 10.5 percent. Applications of a wax-emulsion containing orthophenylphenate and Botran were equally effective in reducing decay (10.3 percent).

Botran residues in samples of fruit commercially treated with Botran in combination with wax or hot water varied between 0.5 and 3.5 p.p.m. In general, the effectiveness of the treatment was related to the levels of the residue. September Grand nectarines treated in Shed D with the wax-emulsion plus Botran developed a relatively low level of decay (9.2 percent) and had a relatively high residue (2.3 p.p.m.). Similarly, lots of Fiesta peaches treated in Shed C with the hot-Botran treatment had a low level of decay (10 percent) and a high residue (3.5 p.p.m.).

TABLE 9.—*Percent weight loss of peaches, plums, and nectarines treated with hot-Botran dips; fruit held 3 days at 70° F. at 75 to 90 percent relative humidity*

Varieties	Percent weight loss in indicated treatment: Check	Hot Botran [1]: 0.5 min.	Hot Botran [1]: 1.0 min.	Hot Botran [1]: 1.5 min.
	Pct.	*Pct.*	*Pct.*	*Pct.*
Peaches:				
Early Coronet	4.3	5.2	5.3	7.1
Gold Dust	6.5	5.8	7.8	8.7
Coronet	5.3	5.6	7.3	7.8
Red Haven	7.2	6.9	7.6	7.7
Red Top	6.0	5.3	5.5	6.1
Elberta	3.7	4.3	4.4	4.5
Duke's Pride	5.9	7.0	7.3	7.9
Average [2]	5.6 a	5.7 a	6.5 b	7.1 c
Nectarines:				
Independent	6.0	5.2	5.3	5.5
Early Sungrand	5.3	5.0	5.6	5.6
Regular Sungrand	5.9	5.1	5.1	5.1
Red Grand	3.0	4.2	4.5	4.4
Le Grand	4.3	4.9	5.8	4.8
Nectarines—Continued:				
Late Le Grand	3.4	4.2	6.5	5.4
Regal Grand	4.3	6.0	5.8	8.3
Gold King	4.9	8.1	8.7	8.9
Average [2]	4.6 a	5.3 a	5.9 b	6.0 b
Plums:				
Late Santa Rosa	5.0	----	5.7	----
Kelsey	1.1	----	1.2	----
Casselman	1.4	----	1.8	----
Average [2]	2.5 a	----	2.9 a	----

[1] Dips in 125° F. water containing ¼ to ⅜ lb. Botran 75W/100 gallons.

[2] Figures not followed by the same letter are significantly different at the 5-percent level.

TABLE 10.—*Percent decay and fungicidal residues on peaches and nectarines treated in commercial packing sheds employing hot-water, hot-Botran, or wax-emulsion plus Botran applications*

Fruit variety	Check	Shed A 125° F., 1.5-minute water dip: Decay	Shed B 125° F., 17-second Botran dip [1]: Decay	Shed B: Residue	Shed C 125° F., 30-second Botran dip [1]: Decay	Shed C: Residue	Shed D Wax emulsion [2] + Botran spray: Decay	Shed D: Residue
	Pct.	*Pct.*	*Pct.*	*P.p.m.*	*Pct.*	*P.p.m.*	*Pct.*	*P.p.m.*
Peaches:								
Suncrest	54.4	17.3	15.6	----	11.7	----	7.2	----
Fay Elberta	18.0	4.0	0.7	0.7	[4] 0	1.0	2.7	2.1
Fiesta	66.0	23.1	20.6	1.4	10.0	3.5	22.9	0.5
Nectarines:								
Le Grand	6.1	0	3.3	----	3.3	----	1.1	----
Late Le Grand	79.4	35.7	38.9	----	23.8	----	22.2	----
Gold King	28.9	3.3	11.7	----	3.9	----	6.7	----
September Grand	61.5	26.2	38.2	0.7	20.8	0.5	9.2	2.3
Average [5]	44.9 b	15.6 a	18.4 a	----	10.5 a	----	10.3 a	----

[1] One fourth to ⅜ lb. Botran 75W/100 gal. (225 to 338 p.p.m. active ingredient) at 125° F.

[2] Applied against rotating brushes as an 8 × dilution of a wax concentrate containing 1.8 percent orthophenylphenate and 7.8 percent sodium dodecylbenzenesulfonate.

[3] Parts per million (p.p.m.) of Botran as determined by the method of Cheng and Kilgore (*3*).

[4] Brown scalded areas on about 20 percent of the treated fruit.

[5] Figures not followed by the same letter are significantly different at the 5-percent level.

DISCUSSION

Heat treatments with hot air or hot water were effective in reducing decay of peaches, plums, and nectarines. The dip treatment, in particular, is practical and can be incorporated into handling systems used in modern commercial packing sheds. The hot-water dip caused no injury or significant weight loss in the varieties tested. Further decay reduction may be achieved by general shed sanitation practices, such as periodic surface sterilization of all field picking boxes and bins, defuzzing brushes, and conveyor belts. Thorough culling of decayed fruit to reduce contamination, and chlorination of the hydrocooling water should further reduce decay.

Heat treatments have the advantage of reducing fungicidal activity without leaving chemical residues on the fruit, but do require relatively long exposure times—25 minutes with hot air, 3 minutes with a hot-water shower, or 1.5 minutes with a hot-water immersion. Shorter exposure times may be used with equal effectiveness if a fungicide is combined with the heat treatment.

Half-minute heated Botran treatments for peaches and nectarines and 1.5-minute treatments for plums were tested extensively on a commercial scale. Of 15 varieties of peach and nectarine tested throughout the season, only two peach varieties were sensitive to the treatment, and about 20 percent of the fruit of these varieties had a slight injury. The injury appeared to be associated with abrasion on conveyor belts that occurred after the hot-fungicide treatments and probably could be reduced or corrected by minimizing the amount of handling after treatment. Reduction of the exposure time to 20 seconds or of the fungicide concentration from 3/8 to 1/4 lb. Botran 75W per 100 gal. water may also reduce injury in these varieties. Of the seven plum varieties tested, only Kelsey was injured by the 1-minute treatment. As there was no significant decay in the untreated Kelsey fruit, Kelseys could bypass the treatment tank or receive shorter treatments to prevent injury.

In laboratory tests, captan performed as well as Botran, when used in combination with a heat treatment. There are reports of injury to fruit treated with captan before harvest and with hot water after harvest (10 minutes at 120° F.) (*2*). In our tests, the 0.5-minute hot-captan dip caused no injury to peach or nectarine varieties tested. However, further testing of other varieties under commercial conditions is needed to determine if any are sensitive to the hot-captan treatment.

The systemic fungicide, benomyl, is significantly more effective than captan or Botran. However, since benomyl is not active against Rhizopus rot (*7*), captan or Botran supplements may be needed to protect fruit from that type of rot. Benomyl in combination with a 0.5-minute heat treatment was outstanding in our tests of fruit in which Rhizopus rot was of minor importance. Significant incidence of Rhizopus rot was limited to the check lots or occasionally to unheated dip treatments.

The experimental fungicide EL–273, also of systemic action, was comparable to benomyl in controlling postharvest decays of peaches. Further testing of this material under different conditions and with additional varieties of fruit is needed.

Applications of wax containing Botran to peaches and nectarines reduced decay to about the same extent as the hot-Botran treatments. Since Botran residues on either waxed or heat-treated fruit were in the same range (0.5 to 3.5 p.p.m.), the effectiveness of the treatments appears to be primarily a function of the residues deposited. This result would suggest that other fungicides, such as benomyl, applied to fruit in combination with a wax treatment would be more effective than cold dips alone, and perhaps as effective as heated dips. Further research is needed to improve the effectiveness of wax treatments and to test the performance of new fungicides in combination with wax.

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