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Use of hot water treatment to control codling moths in harvested California 'Bing' sweet cherries

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Abstract

Preharvest gibberellic acid-treated California 'Bing' sweet cherries (*Prunus avium* L.) were treated with hot water baths (46–58 °C for 0.25–18 min), followed by hydrocooling. The fruit were then stored to simulate either air shipment or sea shipment to overseas markets, both followed by 15 h of shelf life at 20 °C. In separate experiments, cherries were also infested with codling moth larvae and subjected to similar hot water bath heating. The quality attributes showed different sensitivity to the combinations of temperature and time used for hot water bath treatment. Pitting was more common in fruit treated at lower temperatures for longer times, while stem browning was more common in fruit treated at high temperatures. Berry browning, stem color, and pitting were the quality attributes most affected by heat treatment. Browning of cherry stem color was a crucial factor in determining whether a combination of temperature and time for hot water bath treatment was successful. All cherries stored at 0 °C for 14 days to simulate sea shipment were of unacceptable quality after shelf life. Hot water bath treatments that provided 100% codling moth mortality and maintained overall acceptable fruit quality were very limited and included treatments at 50 °C for 10 min and at 54 °C for 6 min. Delaying the hot water bath treatment after fruit harvest, even if the cherries were kept at 0 °C, resulted in a greater loss in fruit quality compared with those treated on the harvest day. Using hot water baths as a quarantine treatment for codling moths (*Cydia pomonella*) on sweet cherries may be feasible if fruit are air shipped at 5 °C for 2 days, but not suitable if fruit are sea shipped at 0 °C for 14 days.

Keywords: Heat; Quality; Quarantine; Disinfestation

1. Introduction

Due to the possibility of codling moth infestation, methyl bromide fumigation is required for California cherry fruit that are exported to Japan (Looney et al., 1996). However, methyl bromide was listed as an ozone-depleting substance in 1992 at the Fourth

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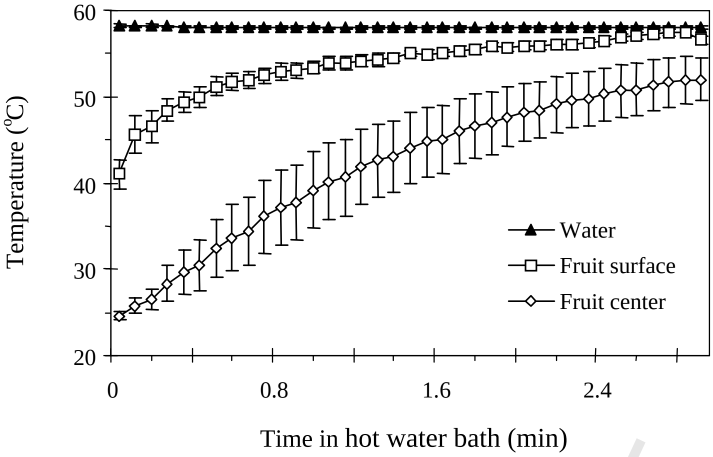

Fig. 1. Temperature profile of water, fruit surface and fruit center during heating of ‘Bing’ cherries with 58 °C hot water for 3 min.

Meeting of the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer, with an estimated ozone-depleting potential (ODP) of 0.4 (UNEP, 2000). Under the Montreal Protocol of the United Nations, methyl bromide will be phased out for soil and structural fumigation in 2005 (USEPA, 2001). Although an exemption exists for quarantine treatments, there are concerns about the possibility of further regulatory actions, and availability and cost of methyl bromide in the future (Mitcham et al., 2001). In fact, the cost of methyl bromide has greatly increased in the past few years (USDA ARS, 2002). Therefore, it is important to develop additional treatment options for quarantine security of California cherries shipped to Japan.

Methyl bromide fumigation has been used as an effective quarantine treatment in cherries for many years. Efficacious doses are reported between 32 and 80 g m^{-3}, dependent upon the variety and treatment condition (Anthon et al., 1975; Lay-Yee, 1989; Hansen et al., 2000a). After fumigation and ventilation, residues of methyl bromide in sweet cherries decreased quickly to under the detection level (Jessup et al., 1994; Hansen et al., 2000b). Methyl bromide fumigation usually causes no deleterious effects on the eating quality of cherry fruit (Anthon et al., 1975), but significant quality loss was reported in some cases (Lay-Yee, 1989). High temperature controlled atmosphere (Neven and Drake, 2000; Shellie et al., 2001), irradiation (Drake and Neven, 1997; Neven and Drake, 2000), and 915 MHz microwaves (Ikediaka et al., 1999) have been explored in an attempt to find effective alternatives to methyl bromide for sweet cherry quarantine treatment. However, there is still no completely satisfactory alternative available that can readily substitute for methyl bromide in efficacy, low cost and ease of use.

Postharvest heat treatments are being used for disinfestation and disinfection of some fruits and vegetables (Smith et al., 1972; Fallik et al., 1993; Lurie, 1998). There is a growing demand to decrease the postharvest use of chemicals to control pathogens and insects. Heat treatments could substitute a non-damaging physical treatment for chemical prevention if a combination of time and temperature could be found to provide the desired control without significant quality loss in the commodity (Lurie, 1998).

We investigated the potential of hot water bath heating for quarantine control of codling moths in California ‘Bing’ sweet cherries by exploring efficacy against the target pest and effect on fruit quality (Fig. 1).

2. Materials and methods

2.1. Fruit materials

‘Bing’ sweet cherries (*Prunus avium* L.) were obtained from harvested field bins in orchards in the San Joaquin Valley of California during the commercial harvest season. All fruit used for the experiments were treated with gibberellic acid by the commercial grower cooperators (gibberellic acid applied once at straw color using 9.9 mg active ingredient per 1 m^2 before harvest). Fruit were immediately transported to the Postharvest Laboratory at The University of California in Davis, CA, and sorted for major defects such as decay or cracking. After sorting, fruit were randomly divided into treatment units. Most of the fruit were directly used for experiments; however, some fruit were placed at 0 °C overnight before being used to investigate the effect of delayed hot water bath treatment.

2.2. Heating equipment and temperature calibration

Hot water bath treatment was conducted in a computer-controlled laboratory scale hot water fruit heating system (model HWH-2; Gaffney Engineering, Gainesville, FL). The heating system is operated and controlled by a microcomputer using a specially developed software package that controls the operation of the system, including reading and logging of fruit and water temperatures, and controlling a stepper motor-driven flow control valve which regulates rates of heat input from hot water heaters to the water tank containing the fruit during heating. The incoming hot water is mixed uniformly with the water in the fruit treatment tanks to maintain uniform water temperature. The system measures, displays and records temperatures to a resolution of 0.01 °C and provides an accuracy of 0.1 °C during operation. Temperature calibration of the heating system is carried out at two points of temperature against a precision thermometer according to the software calibration procedures.

2.3. Hot water bath treatments

Treatment temperatures were determined by the water temperature, not the fruit temperature. Treatment time was counted as the time the fruit was in the hot water.

On the same day of harvest, fruit were subjected to different time and temperature combinations from 46 to 58 °C for 0.25–18 min (Table 1). Chlorine (50 mg l^{-1} sodium hypochlorite) was added to the hot water for disinfection during treatment. The level of chlorine was checked before each treatment and adjusted if necessary. To investigate the effect of delayed hot water bath treatment, a subsample of cherries were held at 0 °C overnight after harvest, then were treated at 52 °C for 5 or 9 min for direct comparison to cherries treated at the same temperature and time on the day of harvest. In an additional experiment, cherries were subjected to three pretreatments, i.e. 40 °C water for 6 min, hydrocooling at 0 °C for 15 min, or no pretreatment, immediately before they were subjected to treatment at 52 °C for 6 min in the hot water bath, to determine if these pretreatments had any influence on fruit response to the hot water bath treatment.

Table 1
Hot water bath treatments

Temperature (°C)	Time (min)
46	8, 10, 12, 14, 16
48	6, 8, 9, 10, 12, 14, 16, 18
50	3, 4, 5, 6, 7, 8, 10, 12
52	1, 2, 3, 4, 5, 7, 8, 9
53	0.5, 1, 2, 3, 4
54	1, 2, 3, 4, 6, 8
56	0.5, 1, 2, 4, 6
58	0.25, 0.5, 0.75, 1, 2, 3

Each treatment had three replicates with 30 cherries each. After treatment, cherries were immediately hydrocooled by immersion in water at 2–3 °C with 50 mg l^{-1} chlorine for 8 min. The 30 cherries of each replicate were then randomly divided into two sub-groups of 15 cherries, gently blotted with cheesecloth, and packaged in two vented plastic bags. One bag was stored at 5 °C for 2 days to simulate air shipment to overseas markets. The other was stored at 0 °C for 14 days to simulate sea shipment to overseas markets to Japan. After storage, fruit were transferred into open mesh baskets at 20 °C with ≥95% relative humidity (RH) for a 15 h simulation of shelf life. Following the shelf life period, fruit quality was evaluated.

There were three controls in the experiments. Thirty untreated cherries were used as untreated control. Thirty cherries immersed in 20 °C water for 12 or 16 min were used as control fruit. And 30 methyl bromide fumigated cherries were used as a fumigated control. For the fumigated control, fruit from the same harvested bins were field sorted and placed in a corrugated box inside a commercial fumigation chamber. Fruit were transported to Davis the following morning after fumigation with 48 g m^{-3} of methyl bromide for 2 h plus 4 h of venting at 12–17.5 °C.

2.4. Temperature monitoring during hot water bath treatment

Eight additional fruit were included with each treatment and eight thermocouple channels were used for temperature monitoring. Four thermocouples measured fruit center temperature and four measured fruit surface temperature. Thermocouples inserted into the center of or placed on the surface of the cherries were secured with narrow strips (3–4 mm wide) of electrical tape distant from the location where temperature was being measured. Temperatures were measured and recorded continuously during treatment.

2.5. Treatment of insect-infested cherries

'Bing' cherry fruit obtained from California and from Washington were artificially infested with third instar codling moth (*Cydia pomonella*) larvae at the USDA ARS in Wapato, Washington. Codling moth larvae were obtained from a colony maintained on a soy-wheat germ-starch artificial diet at 27 °C, 40–58% RH, with a 16:8 h light:dark photoperiod (Toba and Howell, 1991). There were 50 infested cherries per treatment replicate, with one larva placed near the stem end of each fruit. The fruit were held at room temperature (25 °C) overnight to allow the larvae to penetrate the fruit. To simulate commercial operations, the fruit were transferred to 4 °C before hot water treatment. In preparation for treatment, the cherries were placed in a fiberglass mesh bag (made of standard window screen) and the opening sealed with medium-sized paperclips so as to prevent the larvae escaping during hot water bath treatments. Hot water bath treatments were conducted in the same way as for the fruit quality tests at UC Davis. After hydrocooling, the treated fruit were returned to a 25 °C holding room overnight. Codling moth mortality was evaluated the day after treatment according to a previously described method (Hansen et al., 2000a). Moribund larvae were placed on immature organic apples and inspected periodically until they died or pupated.

Table 2
Standards for subjective quality evaluation of cherries

Quality attribute	Score	Description
Berry browning	0	No browning, full red color
	1	Slight browning, affecting less than 0.5 cm^2 surface area, acceptable quality
	2	Severe browning, affecting greater than 0.5 cm^2 surface area, unacceptable
Stem color	0	Green, fresh appearance, less than 30% brown
	1	Substantially green with 30–50% brown
	2	Substantially brown with less than 50% green
Surface pitting	0	None or less than 0.3 cm^2 pitting
	1	Pitting affecting 0.3–0.5 cm^2
	2	Pitting affecting greater than 0.5 cm^2
Surface cracking	0	None or insignificant cracking
	1	Cracking less than 0.5 cm long
	2	Cracking greater than 0.5 cm long
Surface shrivel	0	None or less than 0.3 cm^2
	1	Shrivel affecting 0.3–1 cm^2 surface area
	2	Shrivel affecting greater than 1 cm^2 surface area
Berry decay	0	None
	1	Slight or just beginning, acceptable
	2	Easily visible, unacceptable
Overall acceptability	0	Good commercial quality
	1	Some damage, but still commercially salable
	2	Not commercially salable

2.6. Quality evaluation

All berries in the quality experiments were subjected to a series of quality evaluations after storage and shelf life. The 15 berries in each replicate were first evaluated non-destructively for firmness, external color, berry browning, stem color, pitting, cracking, shrivel, decay and overall acceptability. The details for the criteria used in scoring the subjective quality factors are shown in Table 2. Fruit were then juiced to analyze soluble solids content (SSC) and titratable acidity (TA).

Firmness was measured on each fruit with a FirmTech2 firmness tester (Bioworks Inc.). Color on the two opposite sides of each berry was measured objectively using a colorimeter (Minolta CR300). Three replicates of juice for each treatment were prepared from all 15 berries of each replicate and used for SSC and TA. Juice (4 g) was titrated with 0.1N NaCl solution using an automatic TitraLab TIM850 titrator (Radiometer Analytical, Villeurbanne Cedex, France) for determination of TA. SSC was measured using a refractometer (American Optical Corporation, Buffalo, NY).

For the subjective quality factors (berry browning, stem color, pitting, cracking, shrivel, decay and overall acceptability), an index was used to express a single quality grade for each quality attribute for each replicate using the following formula:

$$\text{Index} = \frac{(\text{number of cherries given score } 2 \times 1.0) + (\text{number of cherries given score } 1 \times 0.5)}{\text{total number of cherries evaluated}}$$

The average index of three replicates was used to indicate the grade for each quality attribute for that treatment. When the average index for a treatment was greater than 0.2, the fruit was considered commercially unacceptable for that quality attribute.

3. Result and discussion

3.1. Cherry quality attributes after various hot water bath treatments

Quality attributes of California ‘Bing’ cherries were influenced by the combinations of temperature and time used in the hot water bath treatments. The quality factors that were most influenced by hot water treatment included berry browning, stem color, pitting and overall acceptability. Other quality attributes, such as cracking, shrivel, decay, firmness, external color, SSC and TA, were not as sensitive to the experimental range of temperature and time combinations. In fact, berry decay was not found in any samples during the experiments. No differences ($P = 0.05$) were found in berry firmness, external color, SSC or TA among all the treatments for both air and sea shipment simulations (data not shown). These results indicate that the hot water bath treatments used in our studies did not exert any negative effect on fruit firmness, color, SSC and TA.

Table 3
Maximum time (min) at various temperatures of hot water bath treatment that resulted in acceptable quality ratings for berry browning, stem color, pitting and overall acceptability after simulated air shipment

Treatment temperature (°C)	Berry browning	Stem color	Pitting	Overall acceptability
46	>16	>16	12	>16
48	>14	>14	9	>12
50	12	7	6	10
52	>9	7	4	7
53	>4	2	>4	>4
54	>6	2	2	4
56	>6	1	2	1
58	>3	>0.25	2	0.75

Cherries were treated on the day of harvest, hydrocooled, packed in vented plastic bags and stored at 5 °C for 2 days for simulation of air shipment to overseas markets followed by 15 h of shelf life at 20 °C. The quality attribute was considered as unacceptable when the average index from three replicates for that attribute was greater than 0.2.

For simulated air shipment, the longest times at each temperature that did not result in an unacceptable rating for a given quality attribute are shown in Table 3. As treatment temperature increased, the time tolerated decreased. In the case of 46 °C, the time was as long as 16 min, but for 58 °C, it was as short as 0.75 min. Different quality attributes showed different sensitivity to the hot water bath treatments. Pitting was more common in fruit treated at lower temperatures for longer times, while stem browning was more common in fruit treated at high temperatures. Stem color was the most sensitive of all the quality attributes evaluated. Following simulated air shipment, treatment times that resulted in unacceptable stem quality were much shorter at most temperatures than those that caused unacceptable berry browning, pitting or overall acceptability. Fruit treated at 58 °C had unacceptable stem color after less than 0.5 min of treatment, while pitting and berry browning were acceptable following 2 and more than 3 min of treatment at the same temperature, respectively (Table 3).

The overall acceptability of cherries after hot water bath treatment was determined by considering all the quality attributes evaluated. Browning of the stem was a crucial factor in determining whether or not a combination of temperature and time for hot water bath treatment was successful. In fact, the main reason for the failure of most hot water bath treatments was because of serious stem browning. However, if berry quality was excellent, cherries with considerable stem browning, but some part still green, were rated as acceptable.

All cherries stored at 0 °C for 14 days to simulate sea shipment followed by a 15 h shelf life period, were commercially unacceptable when all quality factors were considered (overall acceptability), regardless of the hot water treatment applied. The main reason for the unacceptable rating was the presence of very serious stem browning.

The maximum time at each temperature tolerated by ‘Bing’ sweet cherries subjected to simulated air shipment following hot water treatment is shown in Fig. 2. Exceeding the treatment time limits for the treatment temperatures would result in the treated cherries becoming unacceptable after simulated air shipment. Using the regression equation developed from these data, the predicted tolerance for various treatment temperatures agrees fairly well with the experimental data (Table 4).

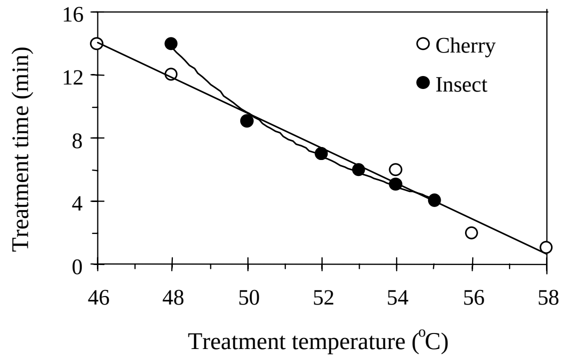

Fig. 2. Maximum exposure time tolerated at each temperature by ‘Bing’ cherry fruit without unacceptable damage following simulated air shipment ($R^2 = 0.986$) and thermal death time (TDT) curve for 100% mortality of fifth instar codling moth larvae ($R^2 = 0.991$).

In our experiments, fruit were placed in open mesh containers during the shelf life period, providing no protection from water loss. Water loss is one of the most critical factors affecting the fresh appearance of both the fruit and stems. Water loss results in rapid desiccation of cherry stems, one of the reasons for serious stem browning. Stems dry out and darken if the humidity is too low (Looney et al., 1996). Sharkey and Peggie (1984) reported that storage at 90–95% RH greatly improved the shelf life and quality of ‘Lambert’ cherries. Mitchell et al. (1975) reported that preharvest antitranspirant spray on cherries reduced water loss and decreased stem browning. Therefore, if fruit had remained in vented plastic consumer bags

Table 4
Experimental and predicted maximum time in hot water at each temperature that resulted in acceptable cherry quality following simulated air shipment and in 100% codling moth mortality

Temperature (°C)	Time for cherry tolerance		Time for codling moth mortality	
	Experimental	Predicted	Experimental	Predicted
50	12	9.6	9	10.0
52	7	7.4	7	7.1
53	>4[a]	6.3	6	6.0
54	6	5.1	5	5.1

[a] For 53 °C, treatment time longer than 4 min was not tested. Predicted time for cherry tolerance to heat treatment and for 100% codling moth mortality were calculated from the equations of treatment time (y) and treatment temperature (x) regression analysis shown in Fig. 2 (for cherry: $y = -1.118x + 65.509$; for codling moth: $y = 7E + 15x^{-8.7382}$), respectively.

that alleviate water loss by maintaining high humidity around the fruit during the shelf life period, there may have been less stem browning.

3.2. Heat transfer during hot water bath treatment

Cherry fruit were treated with hot water, by immersing in water at the target temperature for the designated treatment time. The fruit skin and stems quickly heated to the target temperature, but the center of the fruit heated much more slowly, particularly when it approached the temperature of the water (Fig. 1). For these reasons, the skin and the stem received a more severe heat treatment than the flesh. After a 3 min treatment at 58 °C, temperatures in the hot water bath, on the fruit surface and at the fruit center were 58.1 °C, 56.6 °C and 52.0 °C, respectively (Fig. 1). The average heating rate for the center cherry tissue during hot water bath treatment was 9.1 °C/min. However, the heating rate of the cherry surface and the center flesh tissue was not stable during the 3 min heating period. The heating rate decreased from the first to the second to the third minute of heating, especially for the fruit surface. Because of these differences in the heating rates during the hot water bath treatment, the differences between the final temperatures of the water, fruit surface and fruit center after 3 min of treatment were relatively large (Fig. 1).

Because of the high surface to volume ratio in the cherry stem, it is reasonable to assume that cherry stems absorbed much more heat than other parts of the fruit, although stem temperatures were not measured in our experiments. Stem color was the most sensitive of all the quality attributes evaluated and browning of the stem was a crucial factor in determining whether a hot water bath treatment was successful.

Stem browning is also a concern during sweet cherry storage (Desai and Salunkhe, 1995). The approximate time limit for successful handling of fresh sweet cherries from harvest to market is about 14 days, if transit temperatures do not exceed 2 °C. However, the use of sealed polyethylene liners in containers can extend the cold-storage period at −1 to −0.5 °C by an additional week (Hardenburg et al., 1986). Our results for fruit firmness, external color, SSC and TA after simulated sea shipment to Japan at 0 °C for 14 days did not show any significant differences ($P = 0.05$) between treated, untreated and fumigated fruit. If the problem of stem browning can be resolved, hot water bath treatment could be used as a quarantine treatment for cherries shipped by sea to Japan.

3.3. Insect mortality and cherry quality

A thermal death time (TDT) curve was inferred from the minimum treatment time at each temperature that resulted in complete mortality (Fig. 2). Because in some cases the shortest time resulting in 100% mortality was the shortest time used in the experiments for that temperature, a shorter time may also be effective. The predicted values of the time and temperature combinations that should result in 100% codling moth mortality from the regression curve in Fig. 2 were close to the experimental values (Table 4). By comparing the combinations of time and temperature that resulted in 100% insect mortality with those that were tolerated by the fruit (Fig. 2), combinations that have the potential to be used as a quarantine treatment were identified. Only combinations of time and temperature that fall between the insect mortality curve and the fruit tolerance line have this potential. These acceptable combinations are very limited and include 50 °C for 10 min, 52 °C for 7 min and 54 °C for 5 min. Furthermore, because quarantine security for exports to Japan is at the Probit-9 level, the severity of these treatments would have to be increased in commercial operations. Within the experimental range, temperatures lower than 50 °C resulted in less than 100% insect mortality and temperatures higher than 54 °C resulted in unacceptable fruit quality.

Methyl bromide has been used as an efficacious quarantine treatment for cherry fruit fly (*Rhagoletis cerasi*) and codling moth (*Cydia pomonella*) in cherries (Looney et al., 1996). Early research in the USA (Anthon et al., 1975) indicated that fumigation of fruit with 32 g m^{-3} methyl bromide would completely kill larvae of codling moth. These treatments appeared to cause no deleterious effects on the taste quality of the fruit. However, quality loss in cherries fumigated with methyl bromide has been reported. Lay-Yee (1989) compared six sweet cherry cultivars for their response to methyl bromide fumigation intended to destroy codling moth at a dose of 64 or 80 g m^{-3} for 2 h at 12 °C followed by time and temperature modulations designed to simulate transport to Japan. His results showed that cultivars differed significantly in their tolerance to this treatment and methyl bromide fumigation, in all cases, significantly reduced fruit quality. Our results indicate that hot water bath treatment also caused some quality loss in cherries (Table 3), but combinations of time and temperature were available that provided acceptable quality, as evaluated by industry standards (Table 2), when treated fruit were stored at 5 °C for 2 days to simulate air shipment to Japan. The result of hot water bath treatment with codling moth infested cherries proved that although the acceptable range is limited to a small scope (Fig. 2 and Table 4), hot water bath treatment shows potential as an alternative sweet cherry quarantine treatment.

Although many positive responses of commodities to heat treatments have been reported, there is always a danger of both external and internal tissue damage (Mitcham and McDonald, 1992; Lurie, 1998). In our experiment, internal damage was not observed. However, external damage to the stem was observed. Our results are consistent with other reported results. Smith et al. (1972) reported that treatment of sweet cherries with water at 51.7 °C for 2.5 min or at 46 °C for 5 min to decrease decay caused by *Monilinia* (*Sclerotinia*) *fructicola* did not cause obvious damage.

3.4. Effect of temperature pretreatments on tolerance of cherries to hot water bath treatment

In commercial operation, cherries may be hydrocooled during handling after harvest before they are subjected to the hot water bath treatment. In addition, pretreatment with warm temperatures may affect the tolerance of fruit to higher temperature treatments (Lurie, 1998). Also, the exposure to hot water bath treatments might be reduced by preheating fruit in water to 40 °C, a warm but non-damaging temperature, by allowing the fruit to heat to lethal temperatures more quickly. In a separate experiment, the influence of such pretreatments on fruit response to hot water bath treatment was investigated. The results indicated that cherries treated at 52 °C for 6 min after being subjected to cold temperatures (hydrocooling) or warm temperature pretreatment (water bath) did not show significant differences in quality compared with those cherries only treated at 52 °C for 6 min ($P = 0.05$) after either air or sea shipment simulations. However, the effect of such pretreatments on insect mortality requires further investigation.

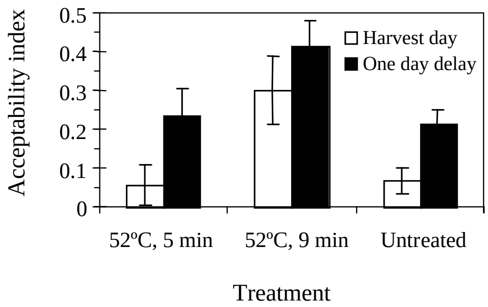

Fig. 3. Overall acceptability of cherries treated on the harvest day or held at 0 °C overnight before treatment. After treatment, cherries were subjected to an air shipment simulation at 5 °C for 2 days followed by a 15 h shelf life at 20 °C before quality evaluation.

3.5. The effect of delayed hot water bath treatment on quality of sweet cherries

Delaying the hot water treatment reduced fruit quality relative to fruit treated on the day of harvest. A one-day delay in applying the hot water bath treatment decreased overall acceptability of cherries after simulated air shipment; however, this decrease in acceptability occurred in both treated and untreated cherries (Fig. 3). Hot water bath treatment should be carried out as soon as possible after cherries are harvested and fruit should be marketed quickly to prevent further deterioration in quality.

4. Conclusions

Berry browning, stem color, and pitting were the cherry quality attributes most affected by heat treatment. Browning of cherry stem color was a crucial factor in determining whether a combination of temperature and time for hot water bath treatment was successful. Hot water bath treatment should be conducted as soon as possible after cherry harvest, as delaying treatment results in an increase in fruit damage.

Using hot water baths as a quarantine treatment to control codling moth in sweet cherries may be feasible if the fruit are air shipped. However, the treatments that provided 100% codling moth mortality and maintained acceptable fruit quality were limited and included treatments at 50 °C for 10 min and at 54 °C for 6 min. Treatments that would provide Probit-9 levels of control have not yet been determined. Hot water bath treatment is not suitable for cherries that will be sea-shipped at 0 °C for 14 days.

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