

Hot water treatment for the control of post-harvest rots on organic cherry

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Introduction

Post-harvest rots of soft fruit can cause serious damage especially during wet seasons. A residue-free treatment that can delay fruit breakdown and development of post-harvest rots: brown rot (*Monilinia spp.*), gray mold (*Botrytis spp.*), rhizopus rot (*Rhizopus spp.*) and blue mold (*Penicillium spp.*) would increase fruit quality to the consumer. At the moment, there are no materials available for organic growers to use to control rots on cherry either pre- or post-harvest.

Heating to kill or weaken plant pathogens offers a potential pesticide-free method to control postharvest diseases. The pathogens can be killed or injured while the host is changed very little. As reported by Barkai-Golan & Phillips (1991), heat treatment of fresh fruits and vegetables for decay control differs from other uses of heat on produce, such as curing to promote wound healing or heating to suppress nematodes, insects or viruses, because these treatments usually require longer heating times than for postharvest decay control. Postharvest heat treatments often are applied for only 3-5 min because the target pathogens are found on the surface or within the few outer cell layers of the produce. Effective water treatments are usually between 46 and 60°C, with exposure times ranging from 30 s to 10 min in fruits such as apple, cherry, cranberry, grapefruit, lemon, litchi, mango, melon, nectarine, orange, papaya, peach, pear, pepper and prune.

Genetic differences among fungi are expressed by considerable variation in sensitivity to high temperature (Figure 1). For a given species, spore inactivation increases with both temperature and duration of the treatment.

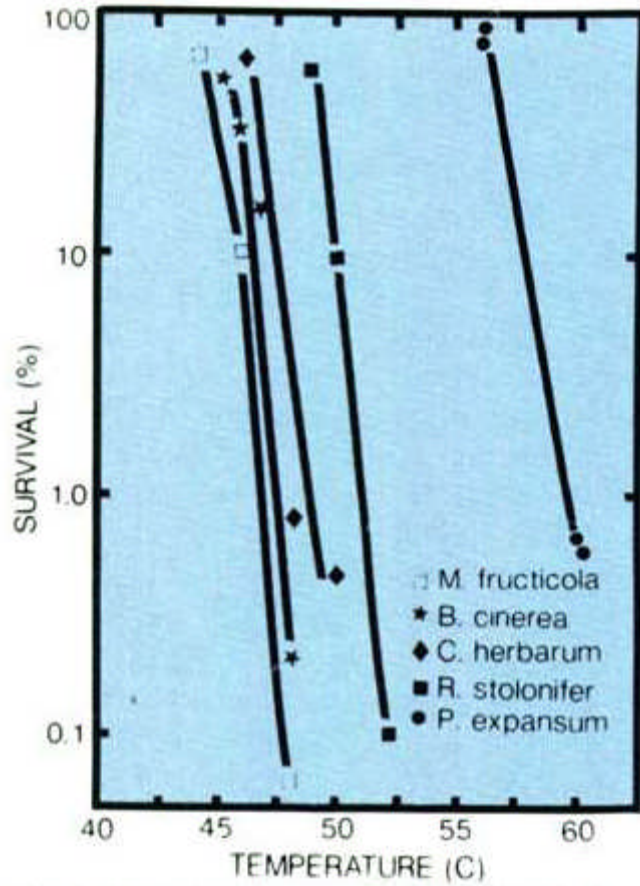


Figure 1: Survival of spores of *Monilinia fructicola*, *Botrytis cinerea*, *Rhizopus stolonifer* and *Penicillium expansum* after 4 min at the indicated temperatures (Sommer et al.1967). Note that *P. expansum* is the fungus most resistant to heat.

A trial was conducted at the Pacific Agri-Food Research Centre (PARC) in Summerland, BC in 2006 on cherry and peach for the control of brown rot (*Monilinia fructicola*) using hot water. The fruit were injured and inoculated. Effective control of brown rot was achieved by dipping in a hot water bath at 50 °C: 1, 2.5 or 4 min for cherry and peach without damaging the fruit (Table 1).

Table 1. Percent fruit brown rot after 8 days at 13 °C on treated cherry and peach in 2006

Dipping temp / time (min)	% Fruit rot	
	Cherry	Peach
20 °C / 2.5	85 ab ¹	78 a
40 °C / 2.5	72 b	68 ab
50 °C / 1	30 c	22 c
60 °C / 2.5 ²	27 c	28 c
50 °C / 2.5	8 cd	33 bc
50 °C / 4	0 d	28 c

¹These values are means of 3 replications: 20 cherries 'Sweetheart' or 6 peaches 'Crest Haven' per replicate. Numbers in columns followed by the same letter are not significantly different at $p \leq 0.05$ as decided by Waller-Duncan k-ratio (k=100) test.

² In 60 °C water, browning was noticed on cherry stems and peach skin was slightly damaged.

Objectives for 2007

- Determine the efficacy of hot water treatment
- Effect on cherry quality
- Identify the modifications to a commercial packing line

Materials and Methods:

Efficacy of hot water treatment

In the laboratory

Prior to applying the hot water technique in a commercial operation, laboratory tests were done at PARC-Summerland, BC on inoculated fruit to obtain preliminary information on the temperatures necessary to control each of the following postharvest rots: blue mold (*Penicillium spp.*), Rhizopus rot (*Rhizopus stolonifer*) and grey mold (*Botrytis mali*) individually. Cherry cv. Bing were harvested at the firm-ripe stage (average weight of 8.4 g per fruit). There were 3 replicates and each replicate contained 20 unblemished cherries with stems placed in a nylon mesh bag. Prior to inoculation, the fruit were injured with a dissecting needle at a depth of 3 mm. On 3 consecutive days, suspensions of each pathogen were prepared: *Penicillium spp.* isolate #2253, *Rhizopus stolonifer* isolate #97-6-16 and *Botrytis mali* #B-153 by collecting spores from an actively growing culture on potato dextrose agar (PDA), in sterile distilled water with a drop of Tween 20 to

help disperse the spores. The suspensions were adjusted to 2.4×10^4 , 3.0×10^4 , 3.0×10^4 spores/ml respectively, and applied on the fruit with a hand atomizer until saturation (approximately 23 ml per group of 20 cherries). The fruit was kept at room temperature in crispers on a sterile grid with 75-100 ml of distilled water at the bottom of the container to keep humidity above 90% around the fruit. The following day each group of 20 cherries was dipped in distilled water in an electronically-controlled water bath (Isotemp 220, Fisher-Scientific, Pittsburgh, PA). Five to 7 L of water was necessary to cover the fruit. The treatments were the hot water dip at 50°C for 2.5 min, 50°C for 2.5 min followed by hydrocooling, 50°C for 4 min, 50°C for 4 min followed by hydrocooling at 55°C for 2.5 min, 55°C for 4 min and a control dip in 20°C water for 2.5 min and 20°C water for 2.5 min followed by hydrocooling. Hydrocooling was an 8 min dip in 0-0.5°C water.

The trial was repeated on cherry cv. Lapin harvested at the firm-ripe stage (average weight of 12.1 g per berry) with the difference that the fruit were not injured and were treated 4 h following inoculation.

The fruit 'Bing' and 'Lapin' were incubated at 20°C until assessed 6-7 days later. The number of cherries infected with the particular pathogen was evaluated using a rating scale of 0 to 2 with 0=not infected, 1=slightly or just beginning, and 2=rot/mold easily visible (Feng, et al. 2004). A quality index was calculated using the following formula:

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

In the packing plant

The second part of the trial was conducted in the transitional organic orchard of Neil and Jackie Sproule in Oyama, BC on cherry cvs Lapin (24, 27 July, 2007) (average weight of 14.3 g per fruit) and Sweetheart (1, 3 August) (ave 12.1 g) freshly harvested. There were 3 replicates and each replicate was a group of 20 unblemished cherries contained in a nylon mesh bag. The fruit were not injured or inoculated. Each group of 20 cherries was dipped in 50°C tap water heated in a propane-operated 50-gallon stainless steel cooker. The treatments were, on 24 July, hot water dip at 50°C for 2.5 min followed by hydrocooling or hydrocooling only. Hydrocooling was a dip of 8 min in the commercial hydrocooler operated on site. On 27 July and 1 August, two treatments were added, hot water dip at 50°C for 2.5 min followed by hydrocooling in sterile distilled water, and hydrocooling in sterile distilled water only. On 3 August, the treatments were, hot water dip at 50°C for 2.5 min followed by hydrocooling, and hydrocooling only and the same two treatments using fruit not previously dipped in a soapy solution (Ecover inc. LA Calif.) normally used at the start of the packing process to prevent bruising of the fruit on the conveyer belt. Following all the treatments, the fruit was brought to the research centre in a cooler, taken out of the nylon mesh bag, put in clean crispers on sterile grids with 75-100 ml of distilled water at the bottom, incubated at 10°C for 2 days. After incubation, the crispers were moved to a 20°C room when they were evaluated 5 to 7 days after treatment.

Water samples were collected on 27 July and 1 August, 2007 from the hot water tank, the hydrocooler and the sterile distilled water used for treated and non-treated. The samples were brought back to the lab where a 0.1 ml sample was spread with a colony spreader on a PDA plate amended with lactic acid (1.5 ml/L of 85% Lactic acid). Dilutions for each treatment were 0, 10^{-1} and 10^{-2} . Half the plates were incubated at 10°C and the other half at 20°C. The plates were assessed for growth after a 3 to 7 day incubation period.

Effect on cherry quality

Fruit quality was assessed 3-7 days after treatment by measuring browning, stem color, surface pitting using a rating scale of 0 to 2 to calculate a quality index (Table 2).

Table 2. Standards for quality evaluation of cherries (Feng et al, 2004)

Quality attribute	Score	Description
Fruit browning	0	No browning, full red color
	1	Slight browning, affecting less than 0.5 cm ² surface area
	2	Severe browning, affecting greater than 0.5 cm ² surface area
Stem color	0	Green, fresh appearance, less than 30% brown
	1	Substantially green with 30-50% brown
	2	Substantially brown with less than 50% brown
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

On 19 and 26 July 2007, groups of 10 unblemished fruit, non-inoculated, were evaluated for quality, treated, incubated in crispers at 20°C and evaluated the following day. Fruit firmness was measured using fruit firmness testers (Firmtech Bioworks, Wamego, KS or Shore analog durometer, Instron Industrial Products, Grove City, PA) and berry browning, stem color and surface pitting were rated using the same 0-2 rating scale. Soluble solids were measured using a refractometer (Model Mark II, Reichert Scientific Inst., Buffalo, NY). Fruit juice was extracted from two cherries in a plastic bag.

Controlling decay at cherry packing plant

For research purpose, the propane-operated stainless steel cooker worked well for the hot water dip. The tank was rinsed, tap water was added and the propane turned on. Enough water to submerge a group of 20 fruit was heated to 50°C in less than 30 min, the burner turned off and the temperature remained constant for the duration of the operation (10-15 min).

Following the heat treatment, the time required for the fruit to reach an internal temperature of 4°C was assessed using thermocouples 8 times from 12 to 26 July on cv Lapin. Internal temperatures were recorded once a minute on 2 cherries each having a separate thermocouple wire inserted in the shoulder at a depth of 10 mm.

Results:

Efficacy of hot water treatment

In the laboratory

There was a significant reduction in *Rhizopus* rot development when the cherries were dipped in 50°C water for 2.5 min for cv Bing and the control was as effective on hydrocooled fruit (Table 3). For cv Lapin, a higher temperature for the same duration was necessary to achieve control: 55°C for 2.5 min.

Table 3. Infection index of 'Bing' and 'Lapin' cherries inoculated with *R. stolonifer*. (Lower index values indicate higher quality fruit)

Dipping temp / time (min)	Bing ¹	Lapin
50°C / 2.5	0.61 ² c	0.74 ab
50°C / 2.5 / Hydrocool	0.67 bc	0.48 abc
50°C / 4	0.89 ab	0.81 a
50°C / 4 / Hydrocool	0.87 ab	0.81 a
55°C / 2.5	0.84 abc	0.11 c
55°C / 4	0.79 abc	0.31 bc
20°C / 2.5	0.96 a	0.65 ab
20°C / 2.5/ Hydrocool	0.94 a	0.52 abc
ANOVA Pr > F	0.0308	0.0296

¹The cherry cv Bing were injured prior to inoculation and cv Lapin were not.

²These values are means of 3 replications: 20 cherries per replicate. Numbers followed by the same letter are not significantly different at $p \leq 0.05$ as decided by Waller-Duncan k-ratio (k=100) t test.

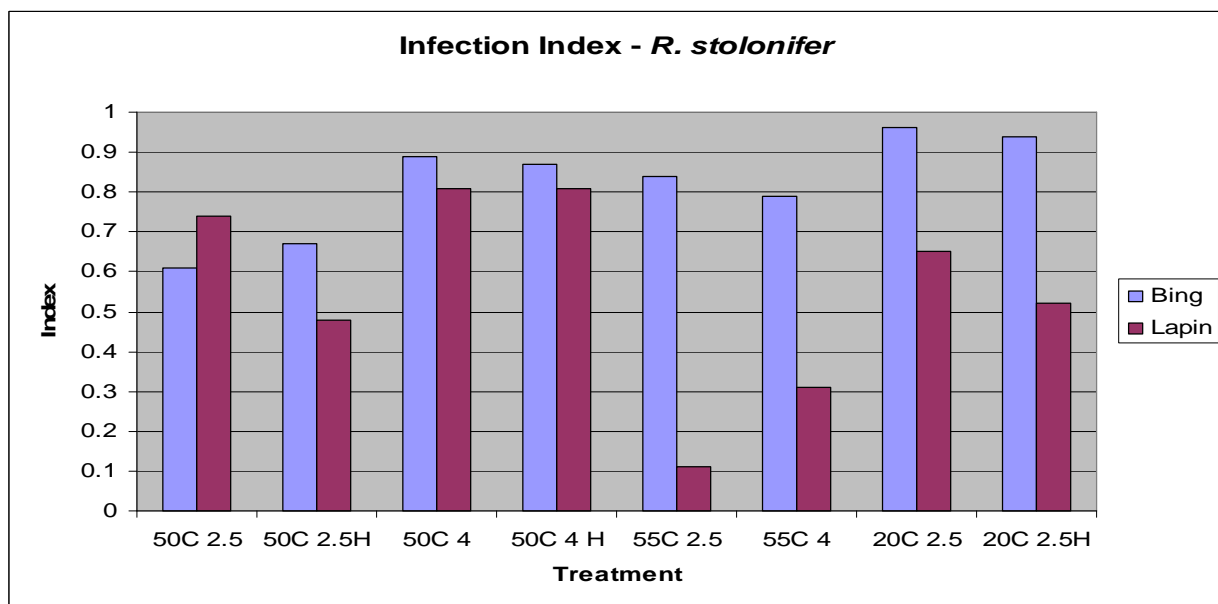


Figure 2: Infection index of 'Bing' and 'Lapin' cherries inoculated with *R. stolonifer*. (Lower index values indicate higher quality fruit)

For *B. mali* inoculated cherry, the 50°C for 4 min treatment (no hydrocooling) reduced significantly the level of infection on 'Bing' (Table 4). There was no difference amongst treatments for 'Lapin'.

Table 4. Infection index of 'Bing' and 'Lapin' cherries inoculated with *B. mali*. (Lower index values indicate higher quality fruit)

Dipping temp / time (min)	Bing ¹	Lapin
50°C / 2.5	0.31 ² bc	0.18 ab
50°C / 2.5 / Hydrocool	0.36 abc	0.38 ab
50°C / 4	0.10 c	0.08 b
50°C / 4 / Hydrocool	0.53 ab	0.47 a
55°C / 2.5	0.53 ab	0.31 ab
55°C / 4	0.62 ab	0.48 a
20°C / 2.5	0.68 a	0.26 ab
20°C / 2.5/ Hydrocool	0.55 ab	0.15 ab
ANOVA Pr > F	0.0144	0.0960

¹The cherry cv Bing were injured prior to inoculation and cv Lapin were not.

²These values are means of 3 replications: 20 cherries per replicate. Numbers followed by the same letter are not significantly different at $p \leq 0.05$ as decided by Waller-Duncan k-ratio (k=100) t test.

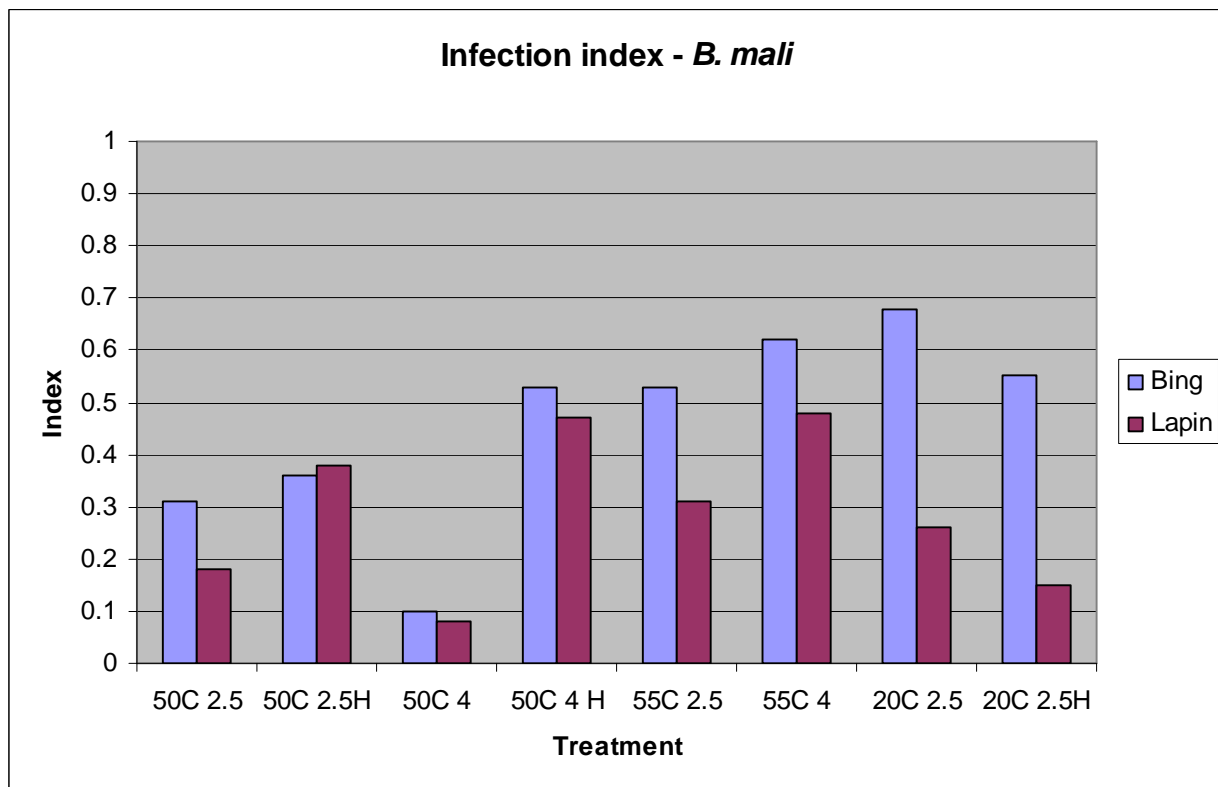


Figure 3: Infection index of 'Bing' and 'Lapin' cherries inoculated with *B. mali*. (Lower index values indicate higher quality fruit)

In the case of *Penicillium spp.* inoculated cherry, there was no difference amongst treatments for 'Bing' (Table 5). On 'Lapin', the 55°C treatments allowed more rot development than the control at 20°C (non-hydrocooled). The same applies to the fruit dipped in 50°C water for 2.5 and 4 min and hydrocooled.

Table 5. Infection index of 'Bing' and 'Lapin' cherries inoculated with *Penicillium spp.* (Lower index values indicate higher quality fruit)

Dipping temp / time (min)	Bing ¹	Lapin
50°C / 2.5	0.74 ² a	0.29 d
50°C / 2.5 / Hydrocool	(n/a)	0.78 a
50°C / 4	0.71 a	0.43 cd
50°C / 4 / Hydrocool	(n/a)	0.66 ab
55°C / 2.5	0.88 a	0.61 abc
55°C / 4	0.91 a	0.66 ab
20°C / 2.5	0.87 a	0.35 d
20°C / 2.5/ Hydrocool	(n/a)	0.47 bcd
ANOVA Pr > F	0.2249	0.0010

¹The cherry cv Bing were injured prior to inoculation and cv Lapin were not.

²These values are means of 3 replications: 20 cherries per replicate. Numbers followed by the same letter are not significantly different at $p \leq 0.05$ as decided by Waller-Duncan k-ratio (k=100) t test.

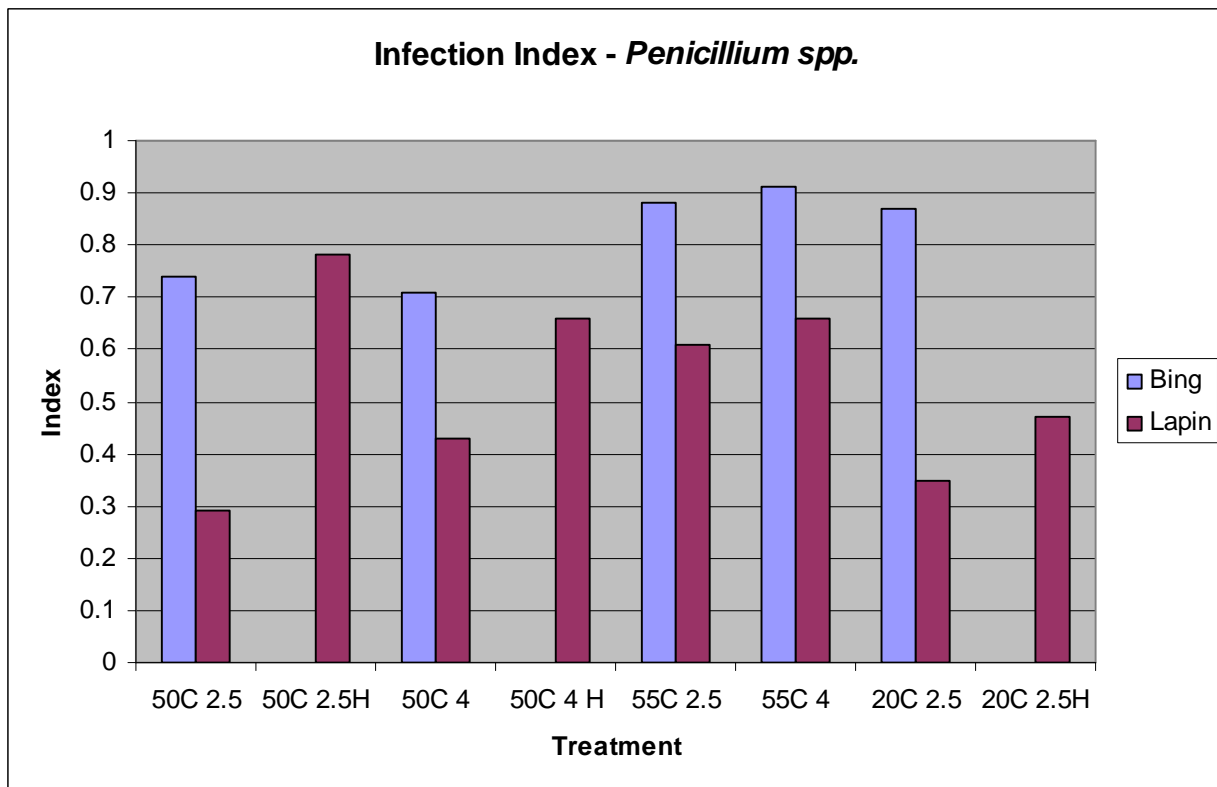


Figure 4: Infection index of 'Bing' and 'Lapin' cherries inoculated with *Penicillium spp.* (Lower index values indicate higher quality fruit)

In summary, on inoculated 'Bing', the heat treatment was effective in reducing the amount of *Rhizopus spp.* at 50°C for 2.5 min and 'Lapin' at 55°C for the same period of time. The treatment at 50°C for 4 min reduced the development of *Botrytis spp.* on 'Bing'. Temperatures of 50-55°C did not effectively control the development of *Penicillium spp.* on either cultivar.

In the packing plant

On 24 July 2007, the treated 'Lapin' cherries developed more rots than the untreated fruit (Table 6). The second time, on 27 July, there was no difference between the treated and untreated fruit whether it was hydrocooled in the commercial hydrocooler or in sterile distilled water. The comparison of hydrocooler water and sterile distilled water was repeated on 'Sweetheart' on 1 August and again the hot water dipped fruit developed more rot than the untreated. There was no difference in rot development when the fruit was hydrocooled in the hydrocooler compared to sterile distilled water. The rots found were mainly *Penicillium spp.* with some *Botrytis spp.* and *Rhizopus spp.* showing.

Table 6. Infection index of 'Lapin' and 'Sweetheart' cherries hydrocooled at the packing plant. (Lower index values indicate higher quality fruit)

Dipping temp / time (min)	'Lapin' (24/07) ¹	'Lapin' (27/07)	'Sweetheart' (1/08)
50°C / 2.5 / Hydrocool	0.30 ² a	0.94 a	0.87 a
50°C / 2.5 / sterile water	(n/a)	0.61 a	0.78 a
untreated / Hydrocool	0.025 b	0.56 a	0.61 ab
untreated / sterile water	(n/a)	0.67 a	0.28 b
ANOVA Pr > F	0.0424	0.2024	0.0307

¹Fruit non-inoculated evaluated after 3 days at 20°C for 'Lapin 24/07', and 7 days for 'Lapin 27/07' and 'Sweetheart 1/08'

²These values are means of 3 replications: 20 cherries per replicate. Numbers followed by the same letter are not significantly different at $p \leq 0.05$ as decided by Waller-Duncan k-ratio (k=100) test.

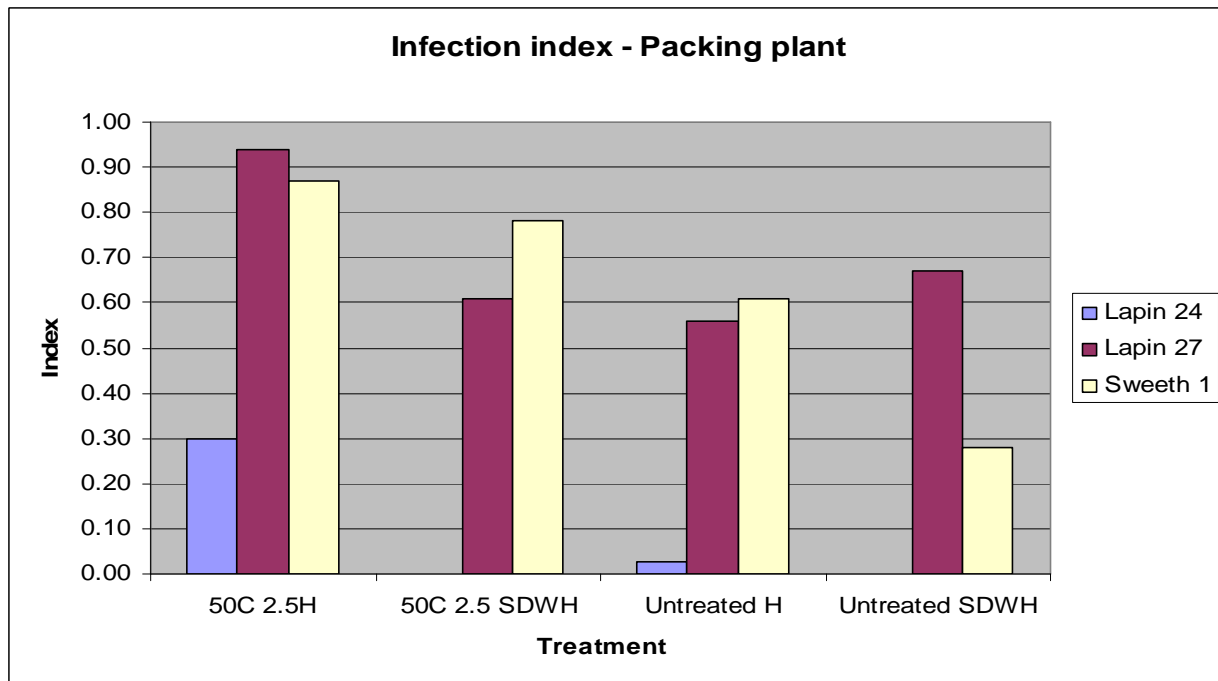


Figure 5: Infection index of 'Lapin' and 'Sweetheart' cherries non-inoculated at the packing plant. (Lower index values indicate higher quality fruit)

The growth of micro-organisms from the water samples collected on 27 July and 1 August 2007 from the hot water tank, the hydrocooler and the sterile distilled water used for treated and non-treated fruit on PDA with 5% lactic acid (L-PDA) was assessed. Different microorganisms, mainly fungal and yeast-like with some bacteria grew at 20°C and 10°C. Similar organisms were detected at both incubation temperatures with a slower growth rate at 10°C (3 days as opposed to 7-10 days). On the plates containing the 'sterile' distilled water used to hydrocool, there was very little growth; on the plates containing the water taken from the hot water tank, there was no growth, and the plates containing the water coming from the commercial hydrocooler had the most numerous and varied microbial growth (Figure 6). The hydrocooler water was changed every 3 days. With a high volume of fruit running through there was an accumulation of microorganisms in the water overtime.

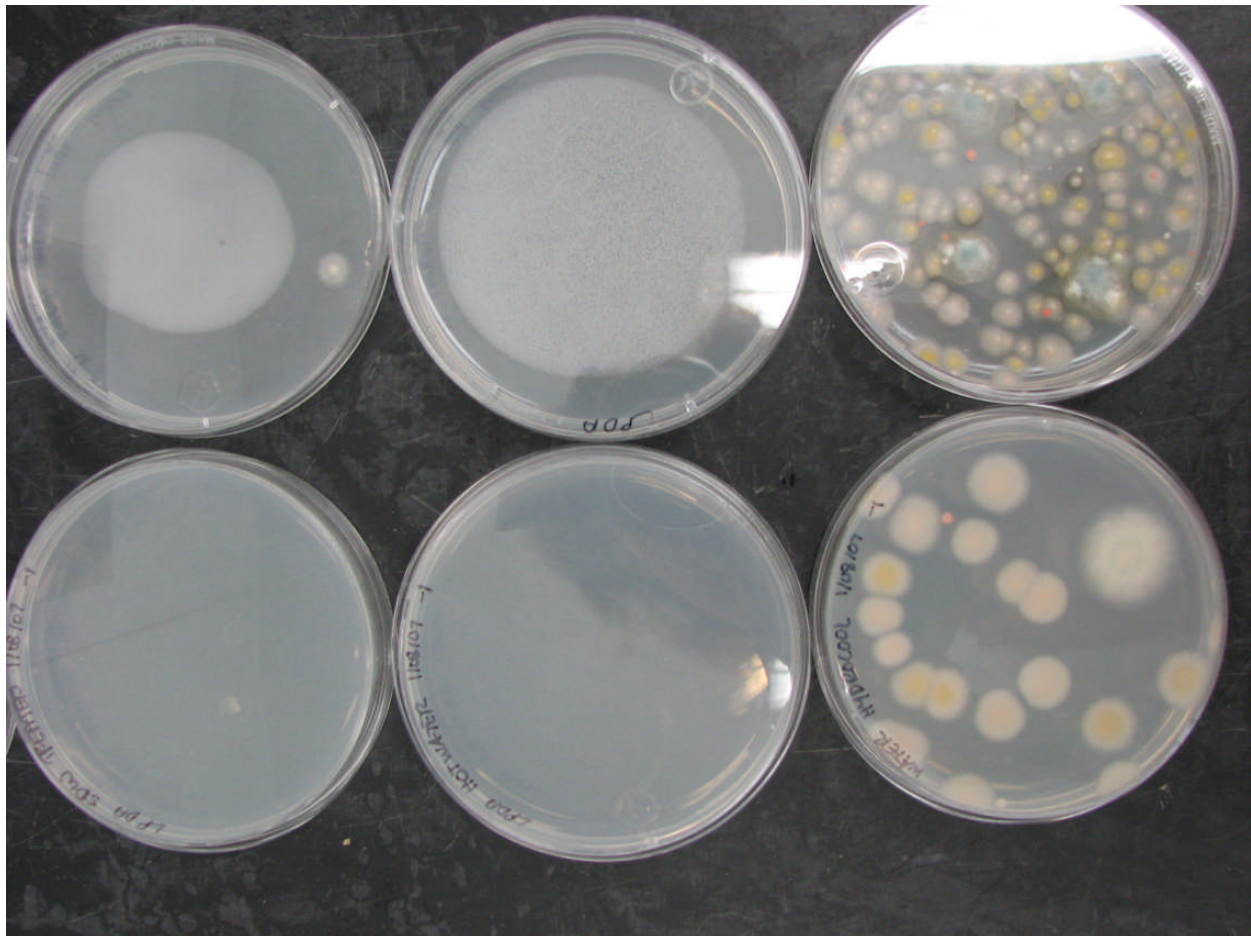


Figure 6: Microbial growth on L-PDA plates: two plates on the left contain the 'sterile' distilled water used to hydrocool; the center two plates contain the water taken from the hot water tank, and on the right: the two plates containing the water coming from the commercial hydrocooler. The hydrocooler water contained high populations of unidentified fungi.

Since the results obtained by treating the cherries in a hot water tank in the commercial operation did not correspond with the results obtained in the laboratory, the pre-treatment of the organic cherries in a soapy solution was examined. The results showed that the treated and untreated cherries taken off the packing line developed more rot than the treated and untreated cherries taken straight from the picking bucket (not dipped in soapy solution) (Table 7). It appeared that the soap solution present on the surface of the fruit made them more susceptible to rot. But the fruit did not benefit from the hot water dip and *Penicillium spp.* developed probably because it is heat resistant.

Table 7. Infection index of 'Sweetheart' cherries with and without 'Ecover' soap. (Lower index values indicate higher quality fruit)

Dipping temp / time (min)	'Sweetheart' (3/08) ¹
50°C / 2.5 / Hydrocooler	0.30 ² a
50°C / 2.5 / Hydrocooler/no soap	0.03 b
untreated / Hydrocooler	0.29 a
untreated / Hydrocooler/no soap	0.06 b
ANOVA Pr > F	0.0207

¹ Fruit non-inoculated evaluated for rots after 5 days incubation at 20°C

² These values are means of 3 replications: 20 cherries per replicate. Numbers followed by the same letter are not significantly different at $p \leq 0.05$ as decided by Waller-Duncan k-ratio (k=100) test.

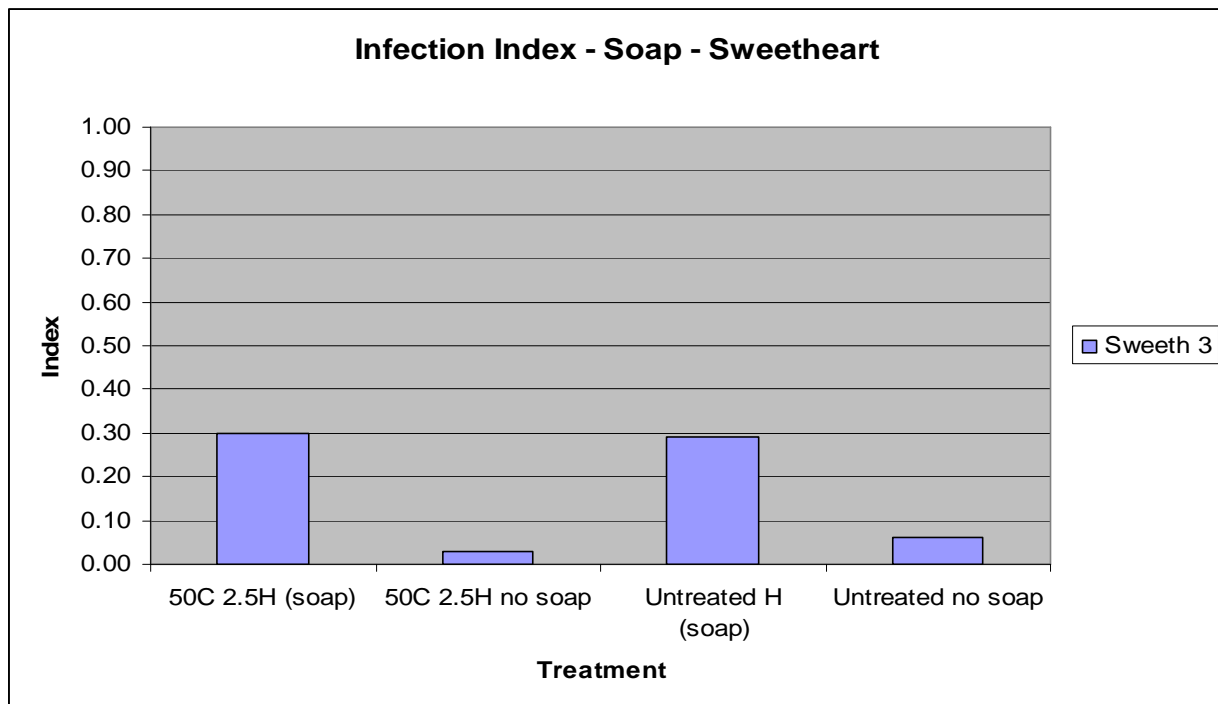


Figure 7: Infection index of 'Sweetheart' cherries non-inoculated with and without a preliminary dip in a soapy solution. (Lower index values indicate higher quality fruit)

In summary, there was no benefit in applying a heat treatment unless fruit was contaminated with decay-causing spores at the packing plant whether it was hydrocooled in the commercial hydrocooler or in sterile distilled water. Water samples were tested for microbial growth and the plates containing the water coming from the commercial hydrocooler had the most numerous and varied microbial growth compared to the plates containing the 'sterile' distilled water used to hydrocool and the plates containing the water taken from the hot water tank. It appeared that the soap solution present on the surface of the fruit made them more susceptible to rot. Overall, the rots found on uninoculated cherry were mainly *Penicillium spp.* (63%) with some *Botrytis spp.* (18%), *Rhizopus spp.* (14%) and the occasional *Alternaria spp.* showing.

Effect on cherry quality

Fruit weighed before and after heat treatment were no different than untreated cherries. For the fruit tested in the laboratory, there was no difference in berry browning between the treated fruit and the control whether hydrocooled or not, but there was significantly less browning on the fruit treated at 50°C than those treated at 55°C (Table 8). Stem color was the best on untreated fruit but there was no significant difference between the treated fruit at 50°C and the untreated when hydrocooled, but at 55°C, the stems showed more browning. Similarly, there was

no difference in surface pitting between the treated fruit and the control whether hydrocooled or not, but the fruit treated at 55°C had more pitting.

Table 8. Quality index for berry browning, stem color and surface pitting of 'Bing' and 'Lapin' cherries tested in the laboratory. (Lower index values indicate higher quality fruit)

Dipping temp / time (min)	Browning	Stem Color	Surface Pitting
50°C / 2.5	0.41 ¹ ab	0.68 bc	0.60 ab
50°C / 2.5 / Hydrocool	0.52 ab	0.81 abc	0.69 ab
50°C / 4	0.38 b	0.70 bc	0.55 ab
50°C / 4 / Hydrocool	0.59 ab	0.82 abc	0.70 ab
55°C / 2.5	0.50 ab	0.83 ab	0.66 ab
55°C / 4	0.67 a	0.87 a	0.81 a
20°C / 2.5	0.43 ab	0.66 c	0.51 b
20°C / 2.5/ Hydrocool	0.41 ab	0.79 abc	0.61 ab
ANOVA Pr > F	0.0787	0.0161	0.0834

¹These values are means of 15-18 replications: 20 cherries per replicate. Numbers followed by the same letter are not significantly different at $p \leq 0.05$ as decided by Waller-Duncan k-ratio (k=100) test.

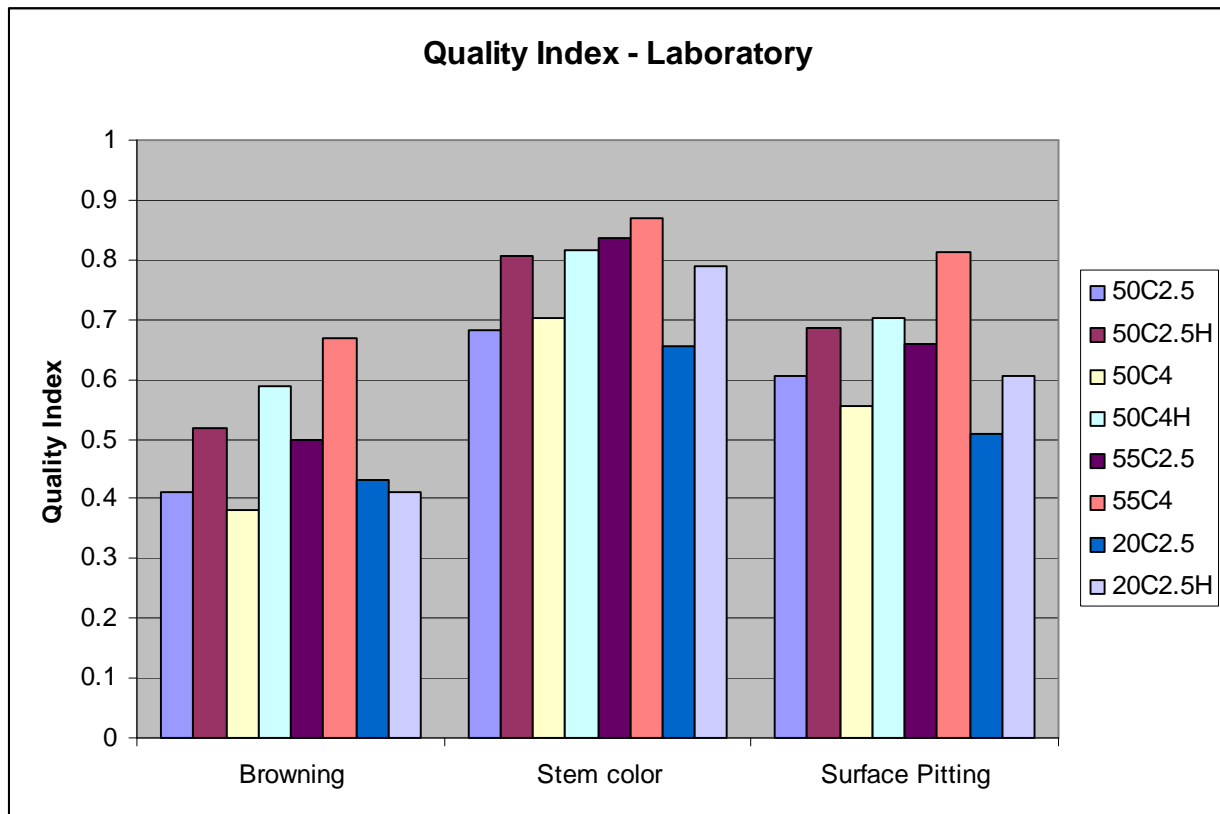


Figure 8: Quality index of 'Bing' and 'Lapin' cherries tested in the laboratory. (Lower index values indicate higher quality fruit)

On the fruit tested in the packing plant, there was more browning on the treated fruit whether hydrocooled in the commercial hydrocooler or in cold sterile distilled water (Table 9). The stem color was better and surface pitting less on the untreated fruit for both hydrocooling systems.

Table 9. Quality index for berry browning, stem color and surface pitting of 'Lapin' and 'Sweetheart' cherries tested in the packing plant. (Lower index values indicate higher quality fruit)

Dipping temp / time (min)	Browning	Stem Color	Surface Pitting
50°C / 2.5 / Hydrocool	0.87 ¹ a	0.68 a	0.90 a
50°C / 2.5 / Sterile water	0.72 ab	0.68 a	0.85 ab
Untreated / Hydrocooler	0.40 c	0.20 c	0.60 c
Untreated / Sterile water	0.52 bc	0.45 b	0.70 bc
ANOVA Pr > F	0.0026	<0.0001	0.0021

¹These values are means of 6-10 replications: 20 cherries per replicate. Numbers followed by the same letter are not significantly different at $p \leq 0.05$ as decided by Waller-Duncan k-ratio (k=100) test.

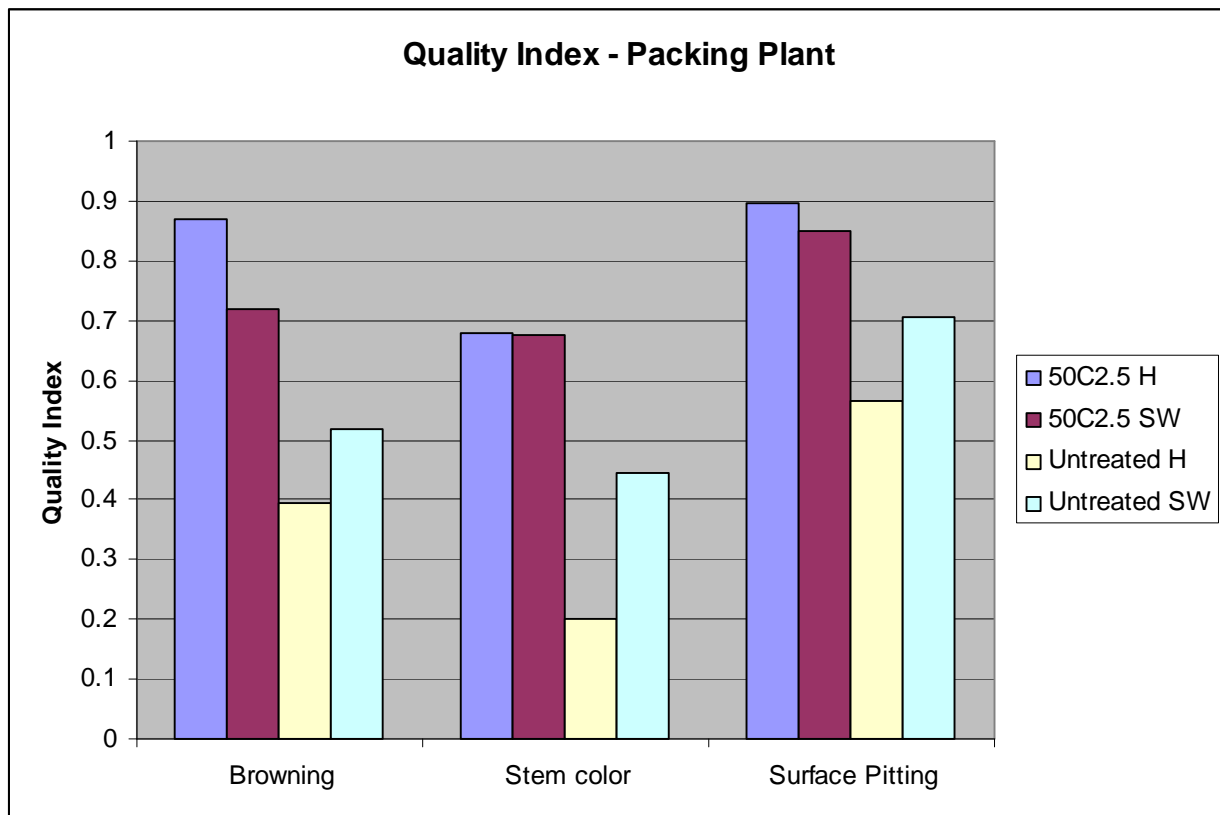


Figure 9: Quality index of 'Lapin' and 'Sweetheart' cherries tested at the packing plant. (Lower index values indicate higher quality fruit)

On 'Lapin' cherries tested in the laboratory strictly for quality on 19-20 and 26-27 July, there was no difference between treated and untreated fruit whether hydrocooled or not for berry browning, stem color and surface pitting when evaluated the day following the heat treatment (Table 10).

Table 10. Quality index for berry browning, stem color and surface pitting of 'Lapin' cherries tested in the laboratory strictly for quality. (Lower index values indicate higher quality fruit)

Dipping temp / time (min)	Browning	Stem Color	Surface Pitting
50°C / 2.5	0.04 ¹	0.18	0.15
50°C / 2.5 / Hydrocool	0.00	0.18	0.13
50°C / 4	0.03	0.13	0.15
50°C / 4 / Hydrocool	0.11	0.13	0.17
20°C / 2.5	0.00	0.15	0.04
20°C / 2.5/ Hydrocool	0.09	0.13	0.06
ANOVA Pr > F	0.4147	0.9835	0.1550

¹These values are means of 6 replications: 10 cherries per replicate. Numbers followed by the same letter are not significantly different at $p \leq 0.05$ as decided by Waller-Duncan k-ratio (k=100) test.

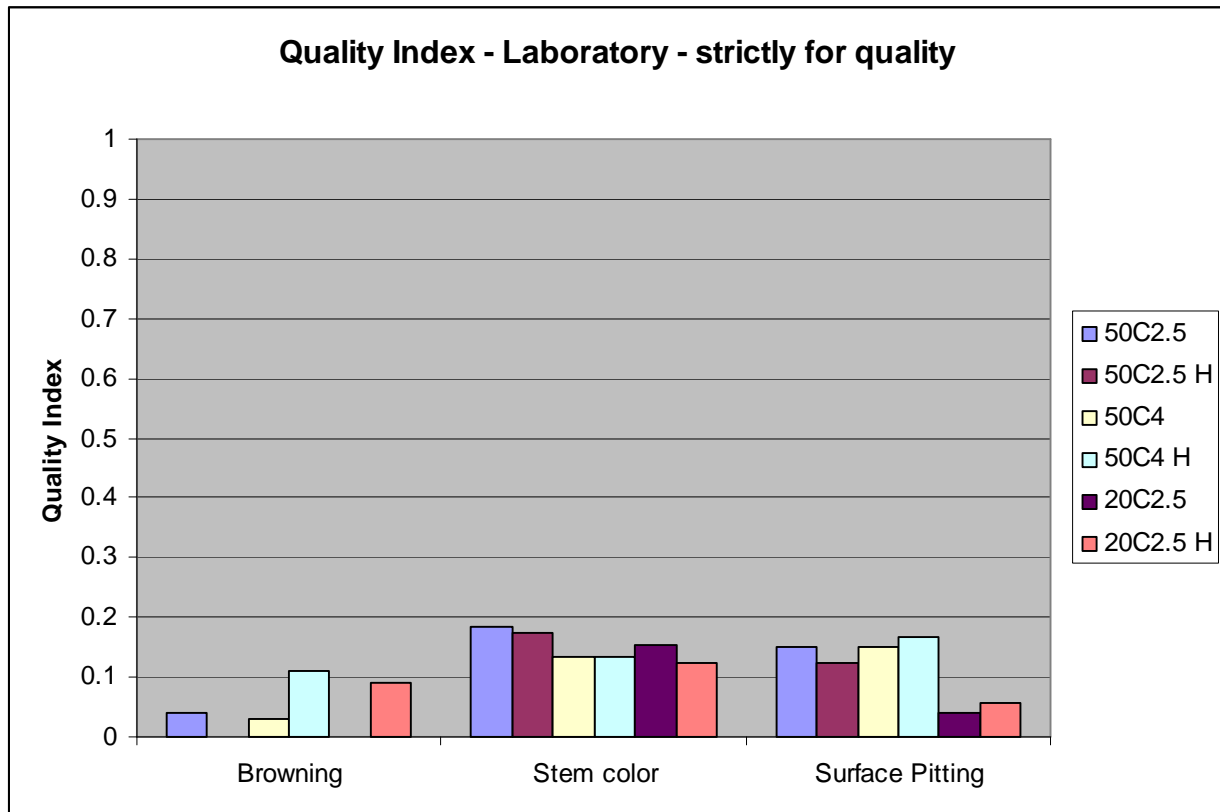


Figure 10: Quality index of 'Lapin' and 'Sweetheart' cherries tested at the packing plant. (Lower index values indicate higher quality fruit)

There was no difference in firmness prior to treatment and after treatment the following day (Tables 11-12). The only significant difference was found on the control where the hydrocooled fruit was firmer when measured with the Firmtech firmness tester. There was no difference in soluble solids after the heat treatment compared with the control.

Table 11. Firmness (g/mm) of 'Lapin' cherries using the Firmtech tester.

Treatment	19 July ¹	20 July
50°C / 2.5	378.9 ² a	359.2 b
50°C / 2.5 / Hydrocool	374.0 a	380.4 ab
50°C / 4	373.8 a	361.4 b
50°C / 4 / Hydrocool	400.7 a	381.3 ab
20°C / 2.5	374.7 a	367.4 b
20°C / 2.5/ Hydrocool	424.7 a	419.8 a
ANOVA Pr > F	0.3906	0.0774

¹These values are means of 3 replications: 10 cherries per replicate. Numbers followed by the same letter are not significantly different at $p \leq 0.05$ as decided by Waller-Duncan k-ratio (k=100) test.

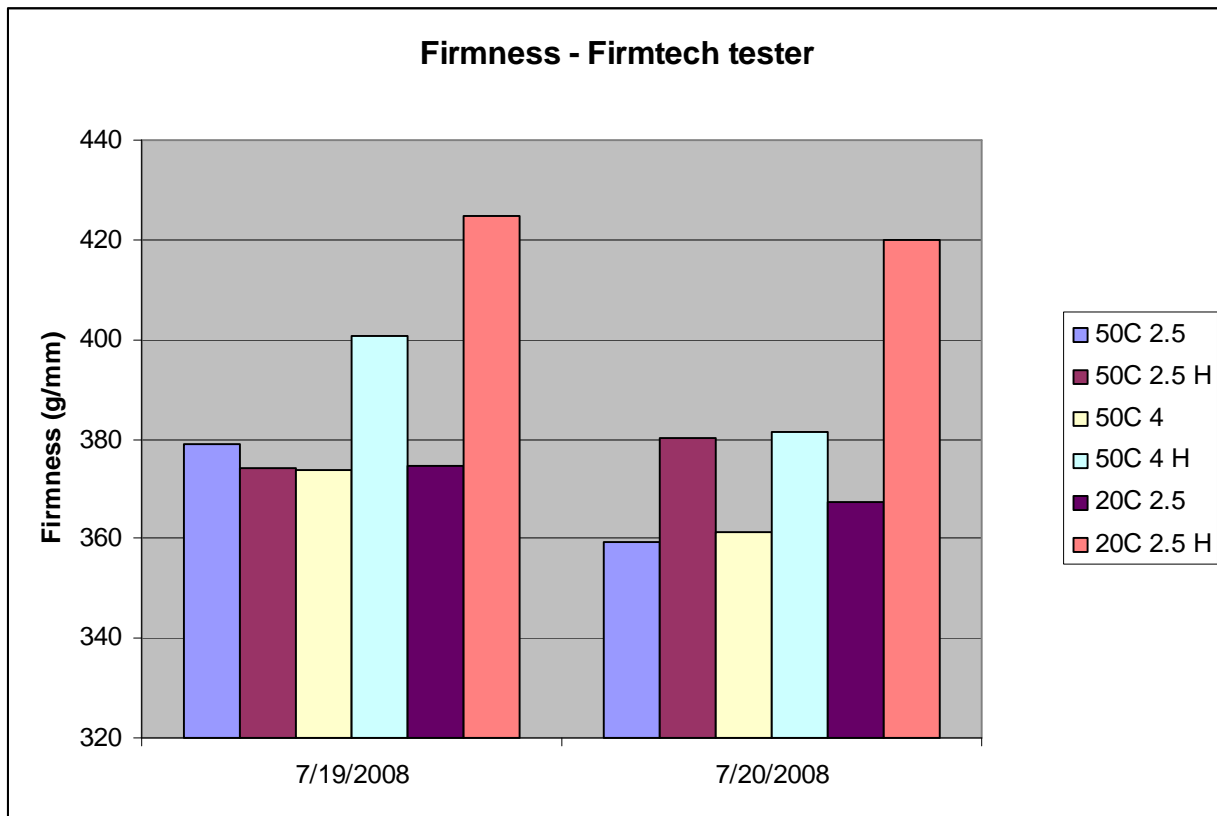


Figure 11: Firmness of 'Lapin' cherries using the Firmtech tester.

Table 12. Firmness (durometer points) of 'Lapin' cherries using the Shore tester.

Treatment	26 July ¹	27 July
50°C / 2.5	64.7 ²	63.0
50°C / 2.5 / Hydrocool	65.0	64.0
50°C / 4	64.7	61.7
50°C / 4 / Hydrocool	65.3	63.3
20°C / 2.5	65.3	64.0
20°C / 2.5/ Hydrocool	66.0	63.3
ANOVA Pr > F	0.9036	0.7618

¹These values are means of 3 replications: 10 cherries per replicate. Numbers followed by the same letter are not significantly different at $p \leq 0.05$ as decided by Waller-Duncan k-ratio (k=100) test.

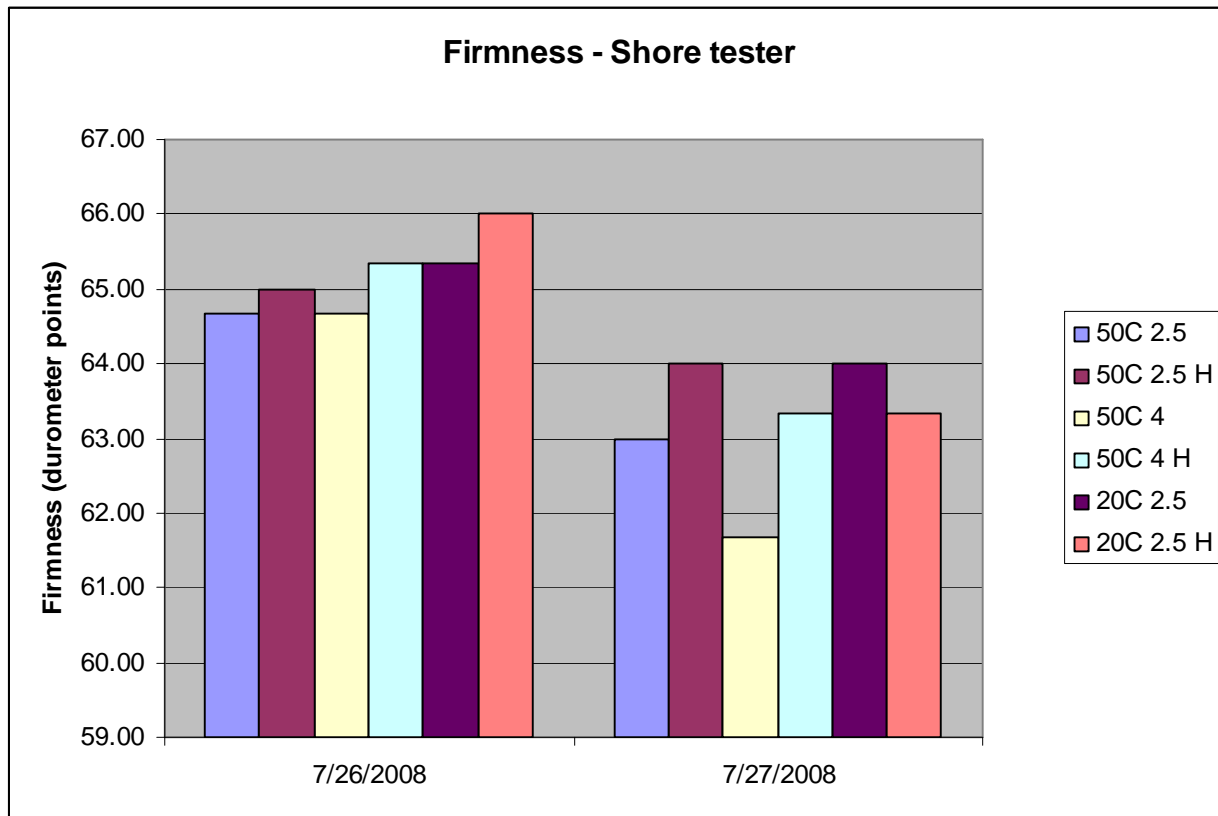


Figure 12: Firmness of 'Lapin' cherries using the Shore tester.

In summary, there was no decrease in fruit quality (berry browning, stem color, surface pitting and firmness) from a heat treatment at 50°C for 2.5 to 4 min when tested in the laboratory, but the quality of the fruit from the packing plant diminished. The use of a soapy solution prior to packing appeared to cancel the advantage of the hot water treatment.

Control decay with hot water at a cherry packing plant

In a commercial operation, the hot water dip would have to be inserted in the packing process after sorting and prior to hydrocooling, using a heated water tank where temperature can be monitored. The time of dipping could be regulated the same way as it is in the hydrocooler by having the fruit move on a conveyor belt at a set speed. Following heat treatment, the average time required to chill the fruit to an internal temperature of 4°C was 11.6 min.

Conclusion

From the tests performed in the laboratory, we can conclude that on inoculated fruit, the heat treatment was effective in reducing *Rhizopus* rot at 50°C (Bing) or 55°C (Lapin) for 2.5 min. The treatment at 50°C for 4 min reduced the development of *Botrytis spp.* on 'Bing'. Temperatures of 50-55°C did not effectively control the development of *Penicillium spp.* on either cultivar. There was no decrease in fruit quality (berry browning, stem color, surface pitting and firmness) from a heat treatment at 50°C for 2.5 to 4 min when tested in the laboratory.

On the other hand, there was no benefit in applying a heat treatment on the non-inoculated fruit from the packing plant. It appeared that the soap solution present on the surface of the fruit made them more susceptible to rot, and fruit quality diminished. The use of a soapy solution prior to packing appeared to cancel the advantage of the hot water treatment.

The rots found on non-inoculated cherries were mainly *Penicillium spp.* (63%) with some *Botrytis spp.* (18%), *Rhizopus spp.* (14%) and the occasional *Alternaria spp.* The incubation temperature (20°C) favoured the development of these rots. For the control of blue mold (*Penicillium spp.*) present on the surface of the fruit, Sommer et al. (1967) showed that a higher temperature is required, up to 60°C, which increases the risk of damaging the fruit (and the stem). However blue mold is not usually as much of a problem on cherries as are brown rot, and rhizopus rot which are effectively killed by the heat treatment.

In conclusion, the hot water treatment is a method that shows promises for the control of *Rhizopus spp.* and *Botrytis spp.* at temperatures of 50-55°C for 2.5 to 4 min. The 2006 results showed control of brown rot at the same temperature and duration. It is a method available to all cherry growers/packers including the organic ones.

Further testing is required to determine the effect of soap solution on the fruit and establish ways to prevent the development of blue mold in storage following a hot water treatment.

References

Barkai-Golan, R. & Philips, D.J., 1991, Postharvest Heat Treatment of Fresh Fruits and Vegetables for Decay Control. *Plant Dis.* 75:1085-1089.

Feng, X., Hansen, J. D., Biasi, B., Tang, J., Mitcham, E. J. 2004. Use of hot water treatment to control codling moths in harvested California 'Bing' sweet cherries. *Postharvest Biology and Technology* 31: 41-49.

Sholberg. P.L. & Boulé, J. 2006. Turning up the heat on brown rot. *British Columbia Fruit Grower*, Winter 2006-2007:23.

Sommer, N. F., Fortlage, R. J., Buckley, P. M. and Maxie, E. C. 1967. Radiation-heat synergism for inactivation of market disease fungi of stone fruits. *Phytopathol.* 57:428-433.