TEMPERATURE MANAGEMENT AND MODIFIED ATMOSPHERE PACKING TO PRESERVE SWEET CHERRY QUALITY

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ABSTRACT

The beneficial effects of proper temperature management include reduced decay, improved firmness and skin color, greener stems, and reduced pitting. Improper handling temperature rapidly reduces shelf life. Modified atmosphere packaging has lengthened the postharvest life of cherry fruit by reducing the rate of growth of decay organisms, retarding softening and retaining stem color. Modified atmosphere films can provide beneficial effects whether they are heat sealed or sealed by turning the bag and closing with tape. Cherries held at 32 ºF do not benefit from modified atmosphere as much as fruit held at slightly warmer temperatures (32 vs. 45 ºF). Cherries held at 32 ºF are superior to those held at 45 ºF after 14 days. Thus modified atmosphere is not a substitute for cold temperature in extending postharvest life.

INTRODUCTION

Sweet cherries are extremely difficult fruit to handle after harvest because they have a short postharvest life due to little storage carbohydrate (starch) and are very susceptible to bruising (pitting). Consequently temperature management is critical. Rapid temperature reduction and close temperature control are required if fruit is to be shipped to distant markets. Over several years we examined the relationship of fruit temperature on the effect of a controlled impact on fruit injury.

There are excellent publications that describe commercially viable methods of temperature reduction (Thompson *et al*., 1998) for fruits as well as factors influencing transit temperatures (Kasmire *et al*., 1982). Although Crisosto *et al*. (1993) found that 'Bing' cherries were one of the least susceptible to bruising, the Washington industry has always had a challenge in minimizing impact bruising that is manifested by pitting. Bruising and pitting are related to temperature and fruit maturity (Lidster *et al*., 1980; Porritt *et al*., 1971; Wade *et al*., 1980).

Crisosto *et al*. (1993) concluded that cherries should be cooled to 32 ºF within 4 to 6 hours after harvest and handled between 50 and 68 ºF to prevent pitting. Washington cherries are hydrocooled twice: upon receipt at the packinghouse to remove field heat, and again as the final step in the sorting process prior to the box filler (Kupferman, 1995; Young, 1994). Patterson (1987) and Hevia *et al*. (1998) describe the consequences of slow heat removal as increased respiration rate (lower sugar levels), moisture loss (shrivel, especially of stems) and an increased risk of decay resulting in shorter shelf life. In some cases cooling does not take place rapidly enough due to design flaws (lack of functioning equipment) or management problems (overloading the system) (Kupferman, 1995).

Another tool used to extend postharvest life is modification of the atmosphere in the shipping container or box. Traditionally, up to 30% of the cherries grown in the Pacific Northwest have been marketed in Asia. Ten years ago most fruit was transported by air, which added significant cost to the final product. In addition, transport by air often required the palletized fruit to sit on airport loading areas in non-refrigerated conditions for extended periods of time. Recently Washington packers have been using modified atmosphere packaging (MAP) to retain the quality of the fruit during sea shipments. This allows the shipper to have more control over temperature but requires additional time in transit. Cherries destined for Japan are not shipped in MAP due to the necessity to have the cherries fumigated.

A number of researchers have worked on the development of MAP for cherries and other similarly perishable fruits including blueberries and raspberries (Beaudry *et al*., 1992; Cameron *et al*., 1995; Gorris *et al*., 1998; Lurie *et al*., 1998; Moyls *et al*., 1998; Reed *et al*., 1995; Zagory, 1997; Zoffoli *et al*., 1988). Modified atmosphere (MA) film technology has utilized microperforated films or films that are unperforated but have a selectively permeability to oxygen and carbon dioxide (Artes *et al*., 1998; Cameron *et al*., 1993). Some commercial films have incorporated ethylene scrubbing agents in their design (PeakFresh) while others have simplified sealing through the use of twist ties or tape rather than heat (LifeSpan). The next generation of films will be 'smart' films that create different permeability rates based on ambient temperature (Cameron *et al*., 1995).

We have performed trials of commercially available MAP films at different temperatures and length of storage to determine their effect on fruit quality. This is a summary of research performed over the past 10 years to determine the effects of MAP on fresh market cherries.

MODIFIED ATMOSPHERE RESEARCH SUMMARY

In 1989, cherries were enclosed in many types of plastic films with the aim to optimize the film used in cherry MAP. A variety of films were evaluated, from unsealed liners to non-permeable wraps injected with gas. For fruit stored at 34 °F, no differences were detected in the quality attributes of soluble solids, acidity, or firmness, regardless of film used. There was also no difference in quality in films that were heat-sealed compared with those that were folded over and sealed with tape. Fruit acidity was reduced, pitting increased, and soluble solids were reduced over time but there were no measurable differences in those factors as a result of the film utilized.

In 1990 and 1991, Bing cherries were treated with different atmospheres in MAP and controlled atmosphere (CA) storage. Firmness was best and pitting least at 9% oxygen (O_2) and 9% carbon dioxide (CO_2) in CA, while bruising and brown discoloration were minimized in air.

In 1995, industry practices were examined to define the parameters for cherry packing in MAP. Commercially packed fruit from three packers was obtained immediately after packing; half of the sample boxes were cut open to allow for comparison of MAP and non-MAP fruit from the same grower. Boxes were held at 34, 45 or 70 ºF and both atmosphere and resultant fruit quality were examined over time. Oxygen levels dropped dramatically in MAP boxes held at 70 ºF to 0% within 2 days. Fruit held at 34 ºF maintained 10 to 12% oxygen for 3 weeks. The carbon dioxide in the boxes at 34 ºF remained at 7% for the same period. At 45 ºF the results were more variable and ranged from 2 to 13% oxygen and 2 to 10% carbon dioxide. After 10 days, there was less decay in MAP fruit at 34 and 45 ºF than in the open boxes. Stems of MAP fruit were greener and more turgid. The color of the fruit in MAP was lighter and brighter. There was no discernable difference in firmness or odor.

Any quality improvements seen in the MAP fruit was not apparent until at least 7 to 10 days after packing. Additionally, the effect of temperature was examined and found to be more effective than atmosphere in retarding decay and senescence (e.g., 34 ºF fruit was superior to any 45 ºF treatment).

In 1998, Bing cherries were evaluated using seven types of MAP bags available to cherry packers in the Pacific Northwest against the standard liner. Five replicates of each type of bag were used; some bags were heat-sealed, some were sealed by tying, and the standard liners were left unsealed. The atmosphere in each bag was determined at regular intervals. After 2 weeks at 34 °F, boxes of each bag type were removed from storage and held at room temperature for 24 hours. Shelf life was judged by sampling fruit from each open box after 5, 7, and 12 days. The remaining boxes were held at 34 ºF for 29 days, allowed to warm for 24 hours, and sampled. The remaining fruit was placed back into 34 ºF storage and resampled after 3 and 5 days.

Fruit stored at 10 to 16% O_2 and 4 to 8% CO_2 held its quality quite well and was similar to fruit stored in the standard liner. Fruit in one liner (3% O_2 and 16% CO_2) was inferior to the rest. After 2 weeks, the MAP bag types did not affect fruit quality (i.e., firmness, acidity, and soluble solids) at the time of opening or during shelf life exams. However, stem browning was affected. After 29 days stem browning and fruit firmness were affected, but no trend was observed. No MAP film provided superior performance on each sampling date. One conclusion from this study is that it is not necessary to heat seal the MAP liner in order to get rapid establishment of a suitable atmosphere and that many of the liners on the market will provide similar post-storage quality providing the oxygen and carbon dioxide levels are within the correct range.

In 1999, five types of MAP liners were evaluated against the standard liner. In this experiment Bing cherries were stored at 34 ºF for 29 days or at 45 ºF for 22 days. There was a lack of significant quality differences in both stem and fruit within the range of 7 to 20% O_2 and 0 to 10% CO_2 at 0°C.

In another experiment, the quality of Bing cherries stored at 34 or 40 ºF for 28 days using a single MAP liner was compared. Again, there were no statistically significant differences in stem or fruit quality in boxes held at the same temperature. Fruit held at 40 ºF had lower firmness, less soluble solids, and lower acidity than fruit stored at 34 °F.

In a third experiment that year, two MAP liners and the industry standard liner were evaluated to test their effect on Lapins cherry quality. After 16 days at 45 ºF and an additional 4 days at 40 °F, fruits in the MAP bags had less pitting, but were lower in acidity and were less firm than fruit in the standard liner.

In a fourth experiment in 1999, in a joint project with Dr. Peter Sanderson (Washington Tree Fruit Research Commission), the effect of MAP on postharvest decay was evaluated. Commercially packed boxes of Bing cherries were stored at either 32 or 40 ºF for 3 weeks after artificially wounding and inoculating fruit with *Penicillium expansum*. The liners did not affect blue mold incidence on the inoculated fruit, but temperature did. Incidence of naturally occurring decay in fruit stored in the MAP liners was half that in the standard liner (15% vs. 31%, respectively). Likewise, naturally occurring decay incidence at 32 ºF was half that at 40 ºF (also approx. 15% vs. 30%). Storage temperature also affected decay incidence.

In 2000, two MAP liners (LifeSpan and Marston) and the standard liner were evaluated at various temperatures to determine the effect of film and temperature. A bin of commercially harvested Bing cherries was carefully divided into standard boxes (20 lb/box) with overmature, immature, and injured fruit eliminated. Three boxes of each MAP liner type were stored at 34, 40, 45, and 70 °F. No fungicide was used on any of the fruit. Fruit was evaluated after 14, 22, 29, and 36 days. Fruit held at 70 ºF was too badly decayed to be analyzed after 14 days.

Conclusions drawn from this experiment were:

- Liner type did not affect fruit weight, soluble solids values, fruit pitting, or fruit color.
- Liner type did not affect firmness or acidity at 34 °F. MAP liners positively affected firmness (Figure 1) and acidity (Figure 2) at 40 and 45 °F. At the later sampling dates cherries in the LifeSpan liners were firmer and more acidic than those in the Marston or standard liners.

Figure 1. Effect of MAP liner on fruit firmness at 40 º and 45 ºF.

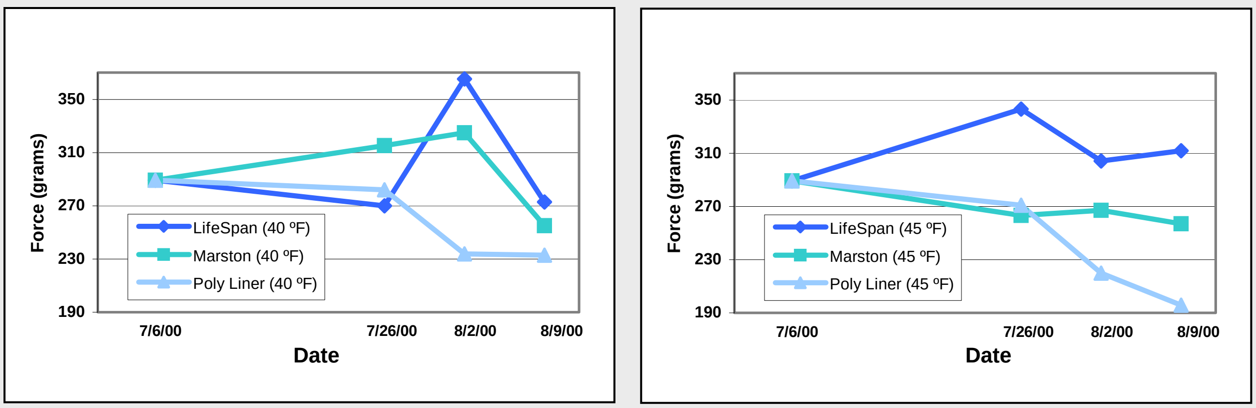
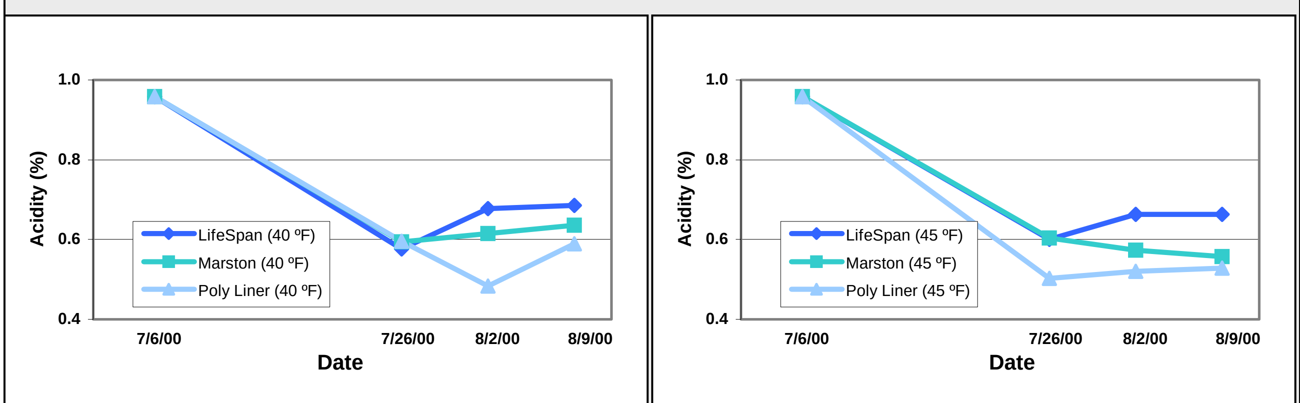


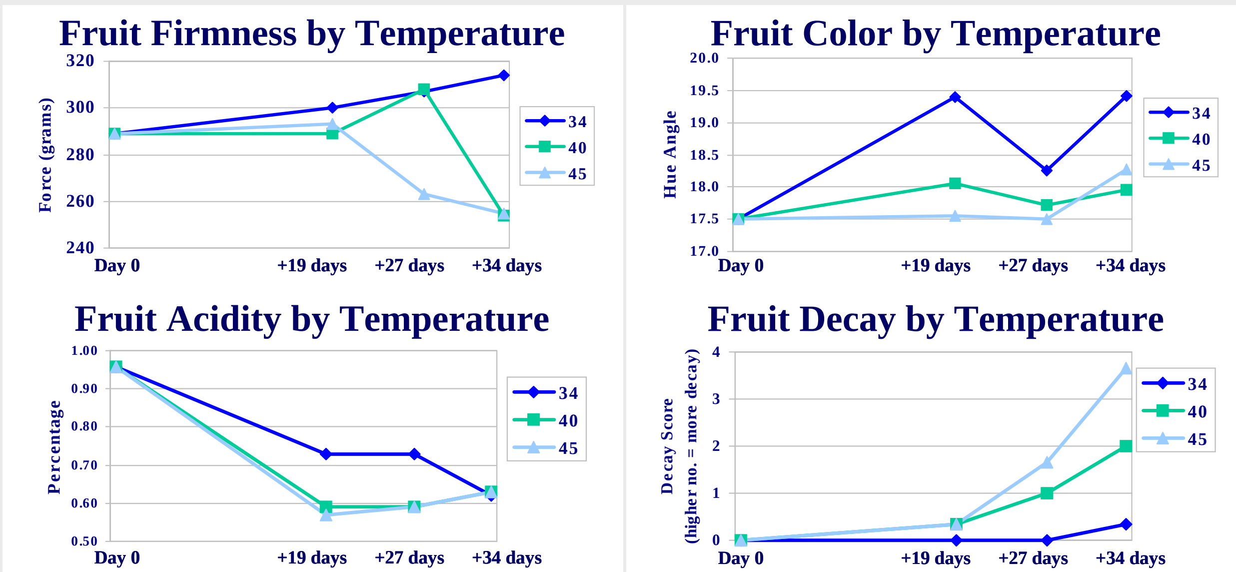
Figure 2. Effect of MAP liner on fruit acidity at 40 º and 45 ºF.



- Liner type did affect decay, with decay developing sooner in the standard liner at temperatures of 40 ºF or greater. The largest amount of decayed cherries was found in the boxes with standard liners. Fruit stored in the LifeSpan liner had less decay than fruit stored in the Marston liner or standard liner.

- The effect of storage temperature was far greater than that of a liner (Figure 3). Problems did not develop at 34 °F, and fruit deterioration was slowed significantly as compared with fruit held at higher temperatures.

Figure 3. Effect of temperature on fruit firmness, acidity, color and decay.



In a separate experiment in 2000 with Dr. Peter Sanderson, Bing cherries were stored in two types of MAP liners (LifeSpan and Grofit) and the standard liner for 31 days at either 34 or 40 °F.

Dr. Sanderson summarized the results as follows:

- Incidence of decay from all causes was greater in fruit stored in standard poly liners at 40 °F than in any of the MAP liners regardless of storage temperature (Table 1). A regular trend was evident that less decay occurred at low temperature than at high temperature. It is clear from these data that keeping fruit cold will extend shelf life by reducing decay losses. In addition, it is also clear that if temperature might become elevated during storage or transit, using a modified atmosphere box liner will minimize losses.

Table 1. Effect of modified atmosphere box liners and storage temperature on naturally occurring decay in Bing cherries 31 days after packing (2000).

Box Liner	Temperature	Disease Incidence (%)*
Poly (standard)	34 °F	22.8 a
Poly (standard)	40 °F	59.1 b
MA LifeSpan	34 °F	20.1 a
MA LifeSpan	40 °F	29.7 a
MA Grofit	34 °F	16.9 a
MA Grofit	40 °F	23.7 a

*Means followed by a common letter are not significantly different. Means were separated using Tukey's test ($P = 0.05$). Data were transformed to arcsine square-root values before two-way analysis of variance. Original, untransformed data are shown.

- The predominant fungi causing decay were *Aureobasidium pullulans* and *Penicillium* spp., which accounted for about 50% and 25% of decay, respectively. The relative frequency of each of the various decay-causing diseases was not affected by the type of box liner used, with the exception of Cladosporium rot. No Cladosporium rot was observed in fruit stored in the Grofit liners, whereas about 14% of decayed fruit were affected by it in LifeSpan liners, regardless of storage temperature. This suggests that further research needs to be done to determine the effects of MAP on the specific fungi that cause postharvest decay in Washington cherries.
- Storage temperature significantly affected the relative incidence of Aureobasidium rot, blue mold, and Mucor rot (Table 2). Incidences of blue mold and Mucor rot were eight and seven times higher, respectively, at 40 ºF than at 34 °F. In 1999, storage temperature affected the incidence of blue mold only and had no effect on the other fungi recovered from decayed fruit.

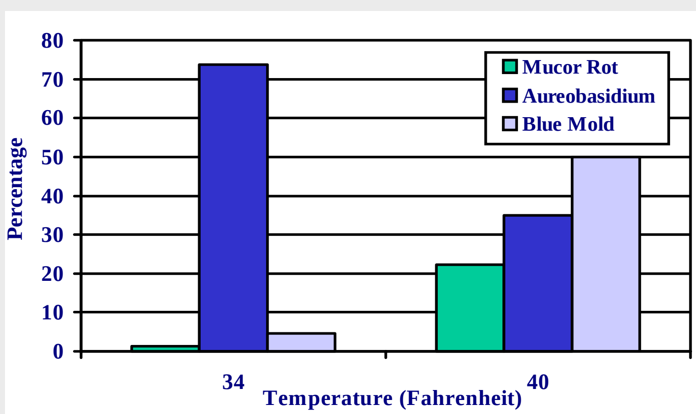
Table 2. Effect of box liner and storage temperature on percentage of diseased fruit affected by naturally occurring postharvest diseases of Bing cherries 31 days after packing (2000).

	Percentage of diseased fruit affected				
	Mucor rot	Alternaria rot	Aureobasidium rot	Blue mold	Gray mold
Box Liner					
Poly (standard)	7.7	5.3	49.0	35.0	8.7
MAP LifeSpan	19.3	8.7	53.7	25.3	3.7
MAP Grofit	8.3	11.7	60.3	21.7	1.0
P =*	*0.619*	*0.109*	*0.617*	*0.587*	*0.168*
Storage Temperature					
34 °F	**1.3**	8.7	**73.8**	**4.7**	1.6
40 °F	**22.2**	8.4	**34.9**	**50.0**	7.3
P =	*0.015*	*0.663*	*0.002*	*0.001*	*0.143*

**P* = significance of *F* statistic from two-way analysis of variance. Data were transformed to arcsine square-root values before two-way analysis of variance. Original, untransformed data are shown.

- Conversely, the relative incidence of Aureobasidium rot was significantly higher in fruit stored at 34 ºF than in fruit stored at 40 °F (Figure 4). It is likely that this is due to secondary invasion of fruit by *Penicillium* spp. and *Mucor piriformis*, which are more virulent pathogens that grow aggressively at 40 °F. This shift was not observed in 1999 and may have occurred in this test because in 2000

Figure 4. Decay organism by temperature.



fruit was stored 10 days longer than in 1999 (31 days vs. 21 days), which gave more time for decay to spread and fruit to senesce. Additionally, relative incidence of Cladosporium rot was significantly higher in fruit stored in standard poly liners at 34 ºF than at 40 ºF (24.5% vs. 0%, respectively), which may also be accounted for by being overrun by *Penicillium* spp. or *M. piriformis*.

- These experiments show the value of packing fruit in MAP liners and cold temperature for reduction of losses for fruit rots. Diseases such as Aureobasidium rot, Cladosporium rot, and Alternaria rot are caused by relatively "weak" pathogens that have been shown to colonize the fruit in the field. Their ability to cause fruit rots is enhanced as the fruit begins to senesce. It appears likely that the effect of MAP liners is to delay the onset of senescence. However, in these tests all fruit was assessed at a single point in time and it is unclear how long this benefit can prolong cherry shelf life.

CONCLUSIONS

- Controlling fruit temperature is a better way to retard decay and senescence than using MAP. Fruit shipped at 34 ºF with good cold chain does not benefit from MAP. Fruit shipped at 40 to 45 ºF benefits from MAP when compared to the standard liner, but will not be as high in quality as that held at 34 °F.
- It is unlikely that any benefit from MAP will be observed in less than 7 to 10 days.
- Many different films are available. Carbon dioxide is the most important component of MAP on cherries. Acceptable films keep the cherries at the desired atmosphere of 10 to 14% CO_2, with 5% O_2.
- It is not necessary to evacuate the atmosphere and heat seal the bag for it to be effective and timely in the establishment of a modified atmosphere for cherries.
- Of the not-heat-sealed liners, LifeSpan film provided the most consistent quality retention. MAP liner manufacturing technology is constantly evolving and new liners could provide increased control of fruit quality.
- Besides affecting decay, the qualities most affected by MAP are firmness and acidity. Other quality components are not affected in a consistent manner. Results often depend on fruit quality at harvest.

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