Quality of Modified Atmosphere Packaged 'Hedelfingen' and 'Lapins' Sweet Cherries

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SUMMARY. 'Hedelfingen' and 'Lapins' sweet cherries (*Prunus avium*) were stored in air or in two types of modified atmosphere (MA) bags (LifeSpan 204 and 208) at 3 °C (37.4 °F) and 90% relative humidity for 4 weeks. Various analytical and quality measurements were conducted weekly on 'Hedelfingen' cherries, whereas on 'Lapins' these were done initially and at the end of 4 weeks. For 'Hedelfingen' cherries, there were differences in carbon dioxide (CO_2) and oxygen (O_2) composition within the MA bags, depending on the bag used. This resulted in slightly better cherry quality for the bag with lower O_2 permeability (L204), which equilibrated at 4% to 5% O_2 and 7% to 8% CO_2. For 'Lapins', the two MA bags showed concentrations of 9% to 10% O_2 and 8% to 9% CO_2 and similar final fruit quality. There was a significant weight loss for the control treatments over time (6% to 13%), whereas the MA treatments showed minimal losses. A higher incidence of cracking and decay was observed in MA treatments of 'Hedelfingen' but not in 'Lapins'. Control cherries had significant shriveling and browning of

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stems; MA-stored cherries had green and healthy stems after 4 weeks. No significant differences were observed in pH, acidity, soluble solids, firmness, and hue angle among the storage treatments. MA packaged cherries seemed to maintain better color than control cherries over time. Similarly, MA cherries had better appearance and eating quality after 4 weeks when compared to control cherries.

Sweet cherries are a very perishable commodity, with a short shelf life in conventional cold storage. Cherry growers have less flexibility in marketing their crop as compared to other crops with extended storage capacity. In many cases, cherries must be sold at low prices to expedite movement and prevent complete losses that can occur once the fruit falls out of condition. Growers in New York state are at a disadvantage compared to their West Coast counterparts because the cherry varieties produced in this region typically have shorter shelf life and limited storage potential. Any method to improve the postharvest life of cherries while maintaining their quality would help New York cherry growers compete in retail markets.

Proper handling and cooling practices, such as hydrocooling, are essential in maintaining sweet cherry quality after harvest. In recent years, sweet cherry quality has been maintained by the use of modified atmosphere packaging (MAP), especially in the large production areas in the western United States (Shelton, 1994). MA bags have been shown to lower respiration rates of fruits and vegetables by altering the O_2 and CO_2 concentrations in the bags (Rai et al., 2002). MA bags can also prevent water loss and fruit shriveling by maintaining a high relative humidity environment (Kappel et al., 2002). Other researchers have also shown that MAP maintained green stems and fruit firmness, both of which are critical for marketing cherries in retail stores (Chen et al., 1981; Drake and Kupferman, 1990; Kappel et al., 2002; Remón et al., 2000). The success of MAP depends on the physical properties of the film, which determine permeability to O_2 and CO_2, and the respiration rate of the products, which is partially dependent on temperature, harvest date, maturity, variety, and other factors (Petracek et al., 2002). According to Kader et al. (1989) fruit ripening is significantly affected when O_2 levels are below 8%, and a greater effect is seen as O_2 levels decline. Also, increased CO_2 levels (above 1%) inhibit fruit ripening and have a cumulative effect along with reduced oxygen levels. Incorrect use of MAP or not matching the product to the appropriate MA film could result in anaerobic conditions leading to product spoilage (Rai et al., 2002).

This study was conducted to determine the effect of two different MA films on ‘Hedelfingen’, a popular sweet cherry variety commonly grown in New York state. ‘Hedelfingen’ is a mid-late to late season sweet cherry with deep red color, medium to medium-large sized fruit with good resistance to cracking, and good flavor and quality. A smaller trial was run with ‘Lapins’, a new variety for New York growers. There has been no prior research with MAP on sweet cherries in New York and therefore our goal was to investigate the potential for MAP to maintain quality and prolong shelf life of sweet cherries grown in New York.

Materials and methods

Sweet cherries var. Hedelfingen were obtained from the New York State Agricultural Experiment Station in Geneva. The cherries were harvested into perforated grape lugs and hydrocooled in 50 $mg \cdot L^{-1}$ (ppm) chlorinated water at 0.5 °C (32.9 °F) for 12 min, within 3 h of harvest. Cherries were allowed to drain for 30 min before being packed into the bags. The treatments studied were air storage (control) and modified atmosphere storage in low-density polyethylene bags (LDPE). The cherries for the control treatment were weighed out and placed in 56 × 36 × 20 cm (22.0 × 14.2 × 7.9 inches) perforated plastic containers. For MAP treatments, cherries were placed in two different bags: LifeSpan L204 and LifeSpan L208 (Amcor Ltd., Melbourne, Australia). These are microperforated, polyethylene bags with different O_2 transmission rates (OTR). L208 bags had an OTR of 1500 cc/bag per day greater than L204 bags. The bags were closed tightly using plastic sealing clips as per the manufacturer’s instructions. The study was designed for a 4-week period with three replications per week for each treatment. Each replicate/bag contained 4.5 kg (10 lb) of sweet cherries (>600 cherries). All the treatments were placed in a storage chamber maintained at 3 °C and 90% relative humidity (RH).

In the second trial, ‘Lapins’ cherries were harvested at a local farm, hydrocooled as described before, and left in cold storage overnight before packing using the two LifeSpan bags L204 and L208. The additional drying time was used to minimize surface moisture, which seemed to increase cracking on ‘Hedelfingen’ cherries. The bags were filled with 9.1 kg (20 lb) of cherries (>1200 units) and sealed tightly. Control cherries were packed in commercial, ventilated cardboard cherry boxes. Each box/bag constituted an experimental unit. The cherries were then transported within 30 min to Geneva where they were stored at 3 °C and 90% RH for 4 weeks. Three boxes/bags per treatment were evaluated at the beginning and at the end of storage only due to limited fruit supply.

Various analytical and chemical measurements were taken on the ‘Hedelfingen’ cherries weekly. Weight loss was determined by weighing undisturbed samples each week. Samples were then sorted to remove cracked and decayed cherries, which were weighed. For stem quality, 10 randomly selected cherries with stems per replicate were visually evaluated for greenness on a five-point scale, with 5 = 80% to 100% green stem, and 1 = 0% to 20% green stem. Oxygen and CO_2 concentrations were measured in the two MAP bags using a PAC CHECK dual headspace analyzer (MOCON, Minneapolis). Color of cherries was measured using a Hunter Ultra Scan XE colorimeter (HunterLab, Reston, Va.). Hunter L, a, b values were measured on 10 cherries per replicate and these were converted to Chroma (C*) and hue angle (h°). For firmness analysis, a puncture test was conducted on 10 cherries per replicate using a TA.XT2 texture analyzer (Stable Microsystems, Scarsdale, N.Y.). A star-shaped pitting probe of 10-mm diameter (0.39 inches) was used to puncture individual cherries to a depth of 30 mm (1.2 inches) at a velocity of 4 $mm \cdot s^{-1}$ (0.16 inch/s). The force required to penetrate the fruit was measured in Newtons. An informal tasting was also conducted each week by the investigators to determine the eating quality and marketability of the cherries.

Soluble solids, pH, and acidity were measured weekly on ‘Hedelfingen' cherries. For soluble solids, a representative sample of cherries was homogenized in a blender and filtered through cheesecloth. The pressed juice was used to take the measurements on a Leica Abbe digital refractometer (Leica, Buffalo, N.Y.). The pH was measured on the juice using a Orion model 370 pH meter (Orion Research, Beverly, Mass.) and for titratable acidity, the juice was titrated against 0.1 N sodium hydroxide until a final pH of 8.2 was reached. Results were expressed as percent malic acid.

'Lapins' cherries were evaluated similarly to the 'Hedelfingen' but only at the beginning and after 4 weeks of storage. Oxygen and CO_2 concentrations were measured weekly by sampling the headspace of unopened bags using gas-tight septa.

All data were subjected to analysis of variance (ANOVA) procedure using Minitab statistical software package (MINITAB, State College, Pa.). Fischer's least significant difference test was used to separate the means when there were significant F values ($P \leq 0.05$).

Results and discussion

'Hedelfingen' trial results. Fruit weight loss was observed over the 4-week storage period in all three treatments. It was very pronounced for the control cherries even though the storage room was maintained at 90% RH, whereas minimal losses were observed for the two MAP treatments. There was about a 13% total weight loss among the control cherries over the 4-week period, while both MAP treatments showed only a 1% loss (Fig. 1). Kappel et al. (2002) reported a 5% weight loss in cherries stored in air for 2 weeks, which is in agreement with the values found in this study.

The O_2 and CO_2 gases in the bags stabilized within 3 d and remained fairly constant throughout the 4 weeks (Figs. 2 and 3). The main difference between the two bags was the final concentration of O_2. This was significantly higher in the L208 bag, which is made from a material with higher OTR, with values around 15% compared to 5% for the L204 bag. Mitcham et al. (2002) reported ideal conditions to preserve the quality of sweet cherries under controlled atmospheres as 3% to 10% O_2, and 10% to 15% CO_2. The L204 bags were able to generate atmospheres closer to these recommended values.

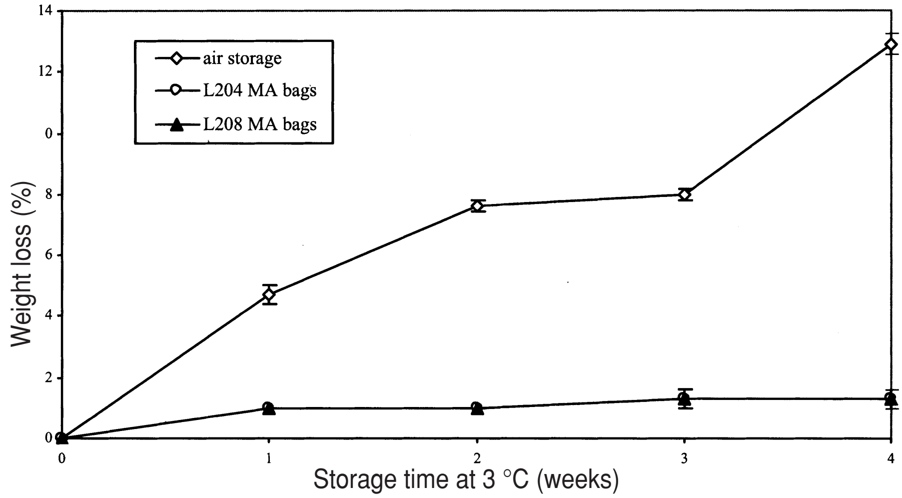

Fig. 1. Percent weight loss of 'Hedelfingen' sweet cherries during air (90% relative humidity) and modified atmosphere storage (MA) at 3 °C (37.4 °F). Vertical bars represent ± standard error for three replications.

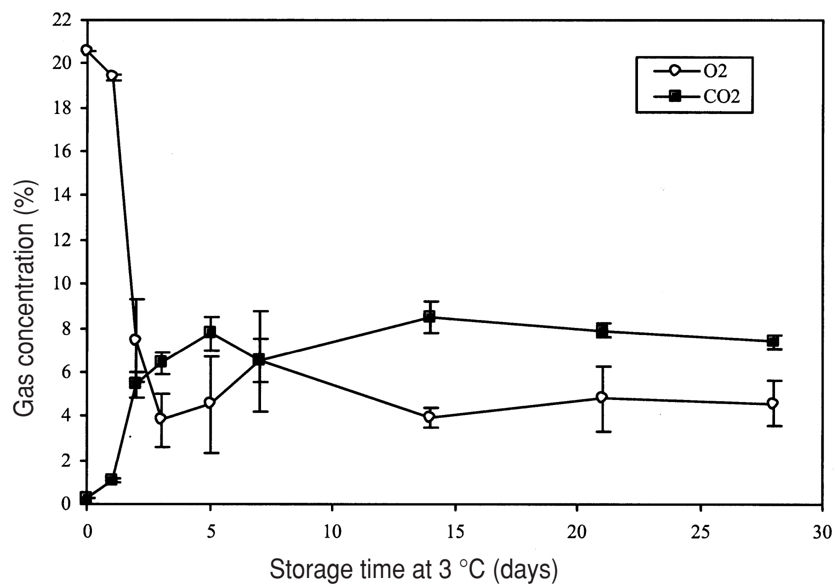

Fig. 2. Change in O_2 and CO_2 composition within LifeSpan L204 modified atmosphere (MA) bags containing 'Hedelfingen' cherries stored at 3 °C (37.4 °F). Vertical bars represent ± standard error for three replications.

The statistical analysis of the quality evaluation of the cherries showed significant differences due to treatments and storage time (see Table 1). The variations observed in pH, acidity, soluble solids, and hue angle were nonsignificant among treatments, whereas changes over time were significant for most attributes except hue angle.

Cracking was significantly higher in both MA treatments compared to the control on each evaluation date (Table 2). The increase in cracking with MA bags was most likely caused by high RH inside the bags, which could have been augmented by not allowing sufficient drying of the cherries after hydrocooling. High RH and water condensation have been reported to cause increased cracking and molding in MA bags (Meheriuk et al., 1995). The incidence of decay was similar for the three treatments over the storage period. The only significant change occurred with the cherries packaged in L208 bags, which showed higher decay at week four compared to the first week. The CO_2 concentration inside L208 bags was below the 10% level normally required to suppress fungal growth significantly (Kader et al., 1989).

Stem color and appearance are important factors for retail sale of fresh cherries. Control cherries showed significant browning and shriveling of the stems after 2 weeks, while the MA cherries maintained green and robust stems for the 4 weeks of storage (Table 2). Kappel et al. (2002) also observed that most of the cherry cultivars exhibited stem browning and shriveling when stored in air as opposed to modified atmosphere storage at 1 °C (33.8 °F). Meheriuk et al. (1997) observed an increase in stem browning of 'Sweetheart' cherries over time in both perforated and nonperforated polyethylene bags. In a previous study by Meheriuk et al. (1995), stems of 'Lapins' sweet cherries remained green after 10 weeks of storage in LDPE bags at 0 °C (32 °F). Chen et al. (1981) observed that 'Bing' cherries maintained their green stems under low O_2 and high CO_2 MA conditions at 1.1 °C (34 °F).

There were no significant differences in pH and titratable acidity (TA) among the treatments (Table 2). A slight increase in pH and a decrease in titratable acidity was seen for all three treatments during storage, but the only significant difference found was for cherries stored in L208 bags, where the final pH rose to 4.12 and the acidity decreased to 0.34%, which represented a 40% loss. Similar observations were recorded by Kappel et al. (2002), where MA-stored cherries had lower TA levels than air-stored fruit. Drake and Elfving (2002) reported a 14% to 23% decrease in TA of 'Lapins' sweet cherries stored at 1 °C (33.8 °F) over a 3-week period. Remón et al. (2000) also reported a decrease in TA of 'Burlat' cherries stored in MAP bags for 3 weeks at 2 °C (35.6 °F).

There were no significant differences in soluble solids (SS) content among the treatments (Table 2). Soluble solids in control cherries showed an increase over time, which can be attributed to weight loss by evaporation, but was nonsignificant due to the sample to sample variation. Kappel et al. (2002) observed a higher increase in the SS content of air-stored cherries than in MA-stored cherries. Remón et al. (2000) and Meheriuk et al. (1995) reported fairly constant soluble solids levels over storage time when cherries were stored in MAP bags.

There were no significant differences in firmness among treatments using the puncture force as an indicator, but firmness did fluctuate among treatments and storage time ranging from 17.8 to 26.7 N (4–6 lbf). Drake and Elfving (2002) reported an increased firmness with longer storage time, which they attributed to moisture loss. Kappel et al. (2002) have reported that air-stored cherries became softer while MA-stored cherries retained their firmness during storage. Remón et al. (2000) also reported a beneficial effect on cherry firmness retention using MAP. Meheriuk et al. (1997, 1995) reported fairly constant firmness values for cherries stored under MA conditions for 8 weeks. Chen et al. (1981) reported increased firmness of 'Bing' cherries under low O_2 and high CO_2 MA storage.

Color values showed significant differences among treatments and over time for lightness and chroma only. Hue angle varied from 14.7° to 16.2° throughout the storage study. Control cherries became duller in appearance after 4 weeks, with significantly lower lightness (L*) and chroma values compared to the MAP cherries. (Table 2). Drake and Elfving (2002) have observed lower L* values in cherries as storage time increased. Meheriuk et al. (1995) observed an initial decrease in L*, followed by an increase and then a final decrease in L* values for MA-stored 'Lapins' cherries. Sharkey and Peggie (1984) have reported that sweet cherries stored at higher RH (95% to 99%) had brighter skin than cherries stored at lower RH at the same temperature.

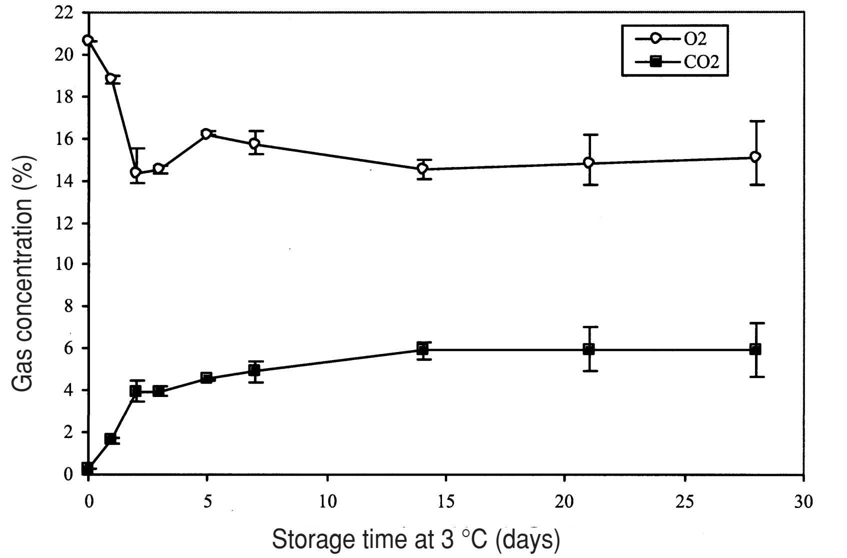

Fig. 3. Change in oxygen O_2 and carbon dioxide CO_2 composition within LifeSpan L208 modified atmosphere (MA) bags containing 'Hedelfingen' cherries stored at 3 °C (37.4 °F). Vertical bars represent ± standard error for three replications.

Table 1. Analysis of variance for various quality factors over storage time and treatment for 'Hedelfingen' cherries.

	Storage time		Treatments		Time × treatment	
Quality factor	**F**	**Significance**	**F**	**Significance**	**F**	**Significance**
Weight loss	87.4	***	185.6	***	33.75	***
Cracked	10.17	***	62.08	***	3.96	**
Decayed	11.91	***	4.28	*	1.54	NS
Stem rating	103.49	***	297.9	***	49.5	***
pH	13.88	***	0.77	NS	2.45	*
Acidity (% malic acid)	10.33	***	1.82	NS	1.84	NS
Soluble solids	3.70	*	0.88	NS	2.35	*
Firmness	2.74	*	0.99	NS	1.16	NS
L* color value	4.68	**	4.26	*	4.80	***
Chroma	19.18	***	8.82	***	3.82	**
Hue angle	2.33	NS	0.13	NS	2.04	NS

NS, *, **, ***Nonsignificant or significant at $P \leq 0.05$, 0.01, and 0.001, respectively.

With respect to eating quality, cherries in all three treatments had acceptable quality for the first 3 weeks in storage (data not shown). At the end of the study, the control cherries tasted sweet and showed noticeable shriveling. Overall quality of the fruit was determined as marginal to poor. The L204 cherries were firm, sweet, with good flavor balance and acceptable quality. The L208 cherries were firm and semisweet with good appearance, but had marginal flavor quality.

'Lapins' trial results. Based on the results from the 'Hedelfingen' study, a second trial was conducted to resemble closer conditions to commercial storage. Fruit was harvested, hydrocooled, and packaged at a local farm equipped with packing facilities. To minimize cracking, cherries were allowed to dry overnight before packing into the MA bags. Control cherries were packed in ventilated cardboard boxes with lids to decrease weight loss by evaporation. The amount of cherries packed per sample was increased to 9.1 kg (20 lb), which is the commercial pack size that the local farm currently uses. Due to limited availability of fruit, samples were only evaluated at the beginning and end of the storage study, i.e, after 4 weeks at 3 °C and 90% RH.

Figure 4 shows the concentrations of O_2 and CO_2 within the two MA bags after packing 'Lapins' cherries and sealing the bags. L204 had lower O_2 and higher CO_2 concentrations after 1 week compared to L208, but these differences were minimal for the rest of the storage time. Unlike 'Hedelfingen', the type of bag did not seem to create a different atmosphere for 'Lapins'. Differences in respiration rate due to variety and maturity may play a role in the results observed. The concentrations of O_2 reached after 2 weeks are within the ideal range of 3% to 10% reported by Mitcham et al. (2002) to preserve the quality of sweet cherries under controlled atmospheres. The CO_2 concentrations were slightly below the recommended range of 10% to 15%.

For the 'Lapins' there were significant changes due to treatments in weight loss, percent decayed, stem rating, pH and chroma. There were also significant changes over time for percent cracked, pH, acidity, soluble solids, chroma, and firmness. Results are presented in Table 3.

Table 2. Quality attributes of 'Hedelfingen' sweet cherries stored under normal and modified atmosphere for 4 weeks at 3 °C (37.4 °F).

Attribute	Treatment[z]	Storage time (weeks) 1	2	3	4
Cracked (%)	Control	0.7 a[y]	1.3 a	1.3 a	1.4 a
	L204	5.6 b	6.7 b	10.1 b	5.1 b
	L208	6.1 b	13.9 b	2.9 b	6.3 b
Decayed (%)	Control	1.1 a	1.3 a	1.8 a	2.7 a
	L204	1.4 a	1.0 a	3.0 ab	3.8 a
	L208	0.9 a[1]	2.2 a[12]	4.2 b[12]	4.4 a[2]
Stem color rating	Control	4.7 a[1]	2.2 a[2]	1.4 a[2]	1.5 a[2]
	L204	4.8 a	4.4 b	4.3 b	4.8 b
	L208	4.9 a	4.3 b	4.4 b	4.7 b
pH	Control	3.89 a	3.96 a	3.97 a	3.99 a
	L204	3.77 a	4.18 a	4.00 a	3.91 a
	L208	3.86 a[1]	4.10 a[2]	3.91 a[1]	4.12 a[2]
Acidity (% malic acid)	Control	0.51 a	0.52 a	0.47 a	0.45 a
	L204	0.61 a	0.40 a	0.46 a	0.45 a
	L208	0.51 a[1]	0.40 a[12]	0.49 a[1]	0.34 a[2]
Soluble solids (%)	Control	16.9 a	16.1 a	18.0 a	18.5 a
	L204	18.9 a	16.0 a	15.6 a	16.8 a
	L208	17.6 a[1]	15.9 a[2]	17.6 a[1]	15.4 a[2]
Lightness (L*)	Control	22.7 b	22.5 a	22.1 a	22.0 a
	L204	22.5 ab	22.6 a	22.5 a	22.9 b
	L208	22.1 a	22.8 a	22.1 a	22.8 b
Chroma (C)	Control	8.8 ab[1]	7.4 a[1]	6.7 a[1]	5.8 a[2]
	L204	9.2 b	8.0 a	8.4 a	8.7 b
	L208	7.4 a	8.1 a	6.9 a	8.2 b

[z]Control = air packing at 90% relative humidity; L204 = LifeSpan L204 modified atmosphere bag; L208 = LifeSpan L208 modified atmosphere bag.
[y]Means in a column (treatments within each week per attribute) followed by the same letter are not significantly different using Fisher's least significant difference (LSD) at $P \leq 0.05$. Means in a row (changes over time per attribute) followed by different numbers are significantly different using Fisher's LSD at $P \leq 0.05$.

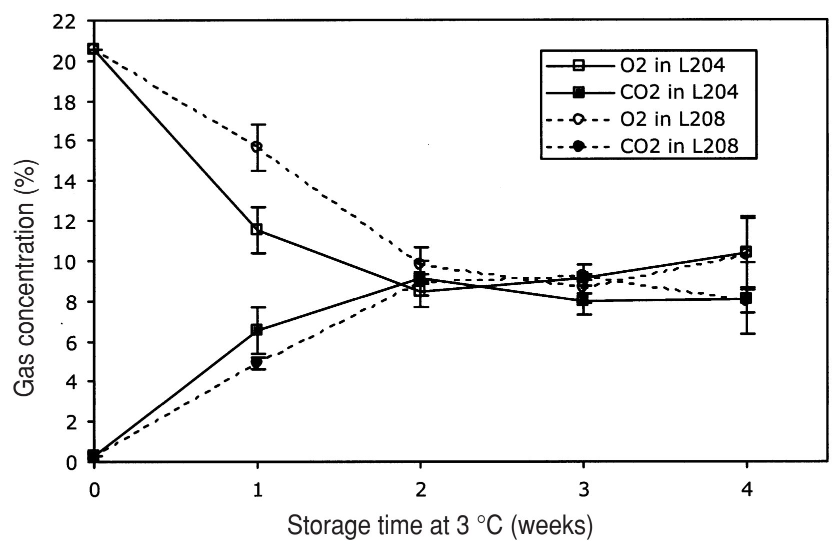

Fig. 4. Change in O_2 and CO_2 composition within LifeSpan L204 and L208 modified atmosphere bags containing 'Lapins' cherries stored at 3 °C (37.4 °F). Vertical bars represent ± standard error for three replications.

Table 3. Quality attributes of 'Lapins' sweet cherries stored under normal and modified atmosphere conditions for 4 weeks at 3 °C (37.4 °F).

Attribute	Treatment[z]	Storage time (weeks) 0	4
Cracked (%)	Control	0 a[y]	0 a
	L204	0 a[1]	0.2 a[2]
	L208	0 a	0.3 a
Decayed (%)	Control	0 a[1]	4.9 b[2]
	L204	0 a[1]	2.6 ab[2]
	L208	0 a[1]	1.4 a[2]
Stem color rating	Control	5.0 a[1]	3.8 a[2]
	L204	5.0 a	5.0 b
	L208	5.0 a	5.0 b
pH	Control	3.86 a	3.92 a
	L204	3.86 a[1]	4.05 b[2]
	L208	3.86 a[1]	4.10 b[2]
Acidity (% malic acid)	Control	0.71 a[1]	0.62 a[2]
	L204	0.71 a[1]	0.59 a[2]
	L208	0.71 a	0.66 a
Soluble solids (%)	Control	18.3 a	16.6 a
	L204	18.3 a	16.6 a
	L208	18.3 a[1]	16.4 a[2]
Firmness (N)[x]	Control	18.1 a	19.2 a
	L204	18.1 a	18.0 a
	L208	18.1 a[1]	15.7 a[2]
Chroma (C)	Control	4.2 a[1]	3.4 a[2]
	L204	4.2 a[1]	4.8 b[2]
	L208	4.2 a	4.0 ab

[z]Control = air packing at 90% relative humidity; L204 = LifeSpan L204 modified atmosphere bag; L208 = LifeSpan L208 modified atmosphere bag.
[y]Means in a column (treatments within each week per attribute) followed by the same letter are not significantly different using Fisher's least significant difference (LSD) at $P \leq 0.05$. Means in a row (changes over time per attribute) followed by different numbers are significantly different using Fisher's least significant difference (LSD) at $P \leq 0.05$.
[x]1.00 N = 0.225 lbf.

Control cherries lost a significant amount of weight in storage, about 6%, after 4 weeks whereas the two MAP treatments did not lose any weight. The weight loss was much lower than 'Hedelfingen', indicating that the covered boxes provided better protection than the plastic lugs. The control cherries had shriveled skin whereas the MAP treatments were still turgid and firm. Results are consistent with previous trials reported by Kappel et al. (2002). Cracking was not a significant problem with the MAP treatments in this trial and it was less than 0.5% after 4 weeks in storage. The additional drying time prior to packing seemed to minimize this defect. The control cherries did not crack either, but they had significantly more decay than the two MAP treatments (Table 3). The lesser amount of decay with MAP in this trial was probably due to fewer cracked cherries and a CO_2 concentration of 8% to 9%, which could decrease the growth of pathogens. MA storage has been reported to reduce susceptibility of fruits and vegetables to pathogens (El-Goorani and Sommer, 1981). Carbon dioxide levels above 10% are required to suppress fungal growth significantly. Higher CO_2 levels (10% to 15%) are known to provide fungistatic effects on commodities that tolerate these levels, such as cherry, blueberry, strawberry, mushroom, okra, and broccoli (Kader et al., 1989). Regarding stem color, control cherries significantly lost green coloration during storage, and became brown and shriveled. The MAP cherries did not experience any browning, showing stems as green as when they were packed in the bags. Similar results were reported by Meheriuk et al. (1995), where stems of 'Lapins' sweet cherries were green after 10 weeks of MAP storage at 0 °C.

There were small but significant changes in pH due to the treatments. The MA cherries had higher pH values than the control. The increase in pH over time was significant for the two MA treatments, while the control cherries did not change after 4 weeks. Titratable acidity did not show significant variations among treatments but did decrease over time for the control and the L204 bagged cherries. Similarly, the soluble solids did not significantly change as a result of the treatments and only L208 showed a significant decrease after the 4-week storage.

Control cherries and L204 bagged cherries maintained their firmness after 4 weeks in storage to at-harvest levels. The L208 bagged cherries experienced a slight but significant reduction in firmness over time. There were no significant changes due to the treatments.

The color values for the 'Lapins' cherries only presented significant differences in chroma. The lightness ranged from 20.6 to 21.3 over treatments and time, while hue angle varied from 7.2° to 10.5°. Color saturation or chroma was significantly higher for the L204 bagged cherries after 4 weeks, indicating a more vivid color. Control cherries had a duller appearance at the end of the study, showing a significant decrease over time. Cherries in L208 maintained the same color values over time. When comparing the cherries at the end of the study, L204 had significantly higher chroma than the control but was not different from L208. These results were slightly different than the ones observed with 'Hedelfingen' cherries, where both MA treatments were better at retaining color than the control.

Eating quality was good for both MA treatments after 4 weeks (data not shown), whereas control cherries had marginal quality and poor visual appearance.

Conclusion

MAP offers a viable option to maintain the quality of 'Hedelfingen' and 'Lapins' cherries under refrigerated storage at 3 °C or below for at least 3–4 weeks. In these trials, different atmospheric compositions were achieved within the two types of bags used for the 'Hedelfingen' cherries; the L204 bag had lower O_2 permeability than L208, resulting in greater reduction of O_2 and slightly better quality after 4 weeks. In the 'Lapins' trial, the gas composition and the fruit quality was similar for both bags. The effect of storage temperature and the response of different varieties to MA packaging materials need to be further studied to better assess optimal conditions to preserve quality and to extend the shelf life of fresh cherries.

Literature cited

Chen, P.M., W.M. Mellenthin, S.B. Kelly, and T.J. Facteau. 1981. Effects of low oxygen and temperature on quality retention of 'Bing' cherries during prolonged storage. J. Amer. Soc. Hort. Sci. 106(5):533–535.

Drake, S.R. and E.M. Kupferman. 1990. Modified atmosphere packaging of sweet cherries. Proc. Washington State Hort. Assoc. 86:210.

Drake, S.R. and D.C. Elfving. 2002. Indicators of maturity and storage quality of 'Lapins' sweet cherry. HortTechnology 12(4):687–690.

El-Goorani, M.A. and N.F. Sommer. 1981. Effects of modified atmospheres on postharvest pathogens of fruits and vegetables. Hort. Rev. 3:412

Kader, A.A., D. Zagory, and E.L. Kerbel. 1989. Modified atmosphere packaging of fruits and vegetables. Crit. Rev. Food Sci. Nutr. 28(1):1–30.

Kappel, F., P. Toivonen, D.-L. McKenzie, and S. Stan. 2002. Storage characteristics of new sweet cherry cultivars. HortScience 37(1):139–143.

Meheriuk, M., B. Girard, L. Moyls, H.J.T. Beveridge, D.-L. McKenzie, J. Harrison, S. Weintraub, and R. Hocking. 1995. Modified atmosphere packaging of 'Lapins' sweet cherry. Food Res. Intl. 28(3):239–244.

Meheriuk, M., D.-L. McKenzie, B. Girard, A.L. Moyls, S. Weintraub, R. Hocking, and T. Kopp. 1997. Storage of 'Sweetheart' cherries in sealed plastic film. J. Food Qual. 20:189–198.

Mitcham, E.J., C.H. Crisosto. and A.A. Kader. 2002. Sweet cherry recommendations for maintaining postharvest quality. Postharvest Technol. Res. and Info. Ctr. 29 May 2003. <http://rics.ucdavis.edu/postharvest2/produce/ProduceFacts/Fruit/cherry.shtml>.

Petracek, P.D., D.W. Joles, A. Shirazi, and A.C. Cameron. 2002. Modified atmosphere packaging of sweet cherry (*Prunus avium* L., 'Sams') fruit: Metabolic responses to oxygen, carbon dioxide, and temperature. Postharvest Biol. Technol. 24:259–270.

Rai, D.R., H.S. Oberoi, and B.Baboo. 2002. Modified atmosphere packaging and its effect on quality and shelf life of fruits and vegetables—An overview. J. Food Sci. Technol. 39(3):199–207.

Remón, S., A. Ferrer, P. Marquina, J. Burgos, and R. Oria. 2000. Use of modified atmospheres to prolong the postharvest life of Burlat cherries at two different degrees of ripeness. J. Sci. Food Agr. 80:1545–1552.

Sharkey, P.J. and I.D. Peggie. 1984. Effects of high-humidity storage on quality, decay and storage life of cherry, lemon and peach fruits. Scientia Hort. 23:181–190.

Shelton, P. 1994. Cherry industry looks to modified atmosphere pack. Good Fruit Grower 5(5):34.