Maintaining Quality of Stored Bartlett Pears with Modified Atmosphere Pallet Covers

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Summary

Introduction

Bartlett pears in California are mostly stored in regular cold storage. The absence of controlled atmosphere storage facilities limits storage life to approximately 3 ½ months maximum and potentially shorter depending on the storage temperature and harvest date. Storing pears under controlled or modified atmosphere with elevated carbon dioxide and reduced oxygen atmospheres can maintain firmness and green skin color and slow the development of storage scald, senescent scald and internal breakdown. However, storage under excessive carbon dioxide, especially of very mature fruit, can lead to internal browning damage and therefore the process must be carefully managed.

Modified atmosphere techniques can provide atmospheres similar to controlled atmospheres; however, the respiration of the product is used to modify the atmosphere inside a “breathable” film rather than using an automated system to flush the atmosphere with nitrogen or add air as needed to maintain the atmosphere within exact setpoints. The modified atmosphere technique has been applied as bags, box liners and pallet covers. Because it is critical to force-air cool Bartlett pears immediately after packing, bags and box liners are not suitable. However, the pallet cover can be applied to thoroughly cooled product inside the cold room. The use of modified atmosphere pallet covers may provide a feasible method to extend the storage life of a portion of the crop to allow more marketing flexibility.

Materials and Methods

Fruit source and treatment

Bartlett pear fruit were obtained from a packinghouse in the Sacramento area. Fruit were sourced from two different areas, Sacramento County and Lake County (Table 1). The fruit had been packed into boxes and stored at 32 – 34°F for 1 to 6 days prior to covering the pallets and initiation the modified atmosphere treatment. The fruit were packed in wrapped, tight-fill or Cosco single-layer trays. There were three harvest dates for the Sacramento County fruit and two harvest dates for Lake County fruit. Two pallets were covered on each harvest date. The treatment consisted of covering cold pear pallets with a Lifespan modified atmosphere (MAP) pallet shroud for up to 3 months. The LifeSpan PS856 pallet shrouds were supplied by Xpedx in Stockton, California for the trial. This particular pallet shroud is designed for 1,800-2,100 pounds of Bartlett pears. The initial firmness of the fruit was measured the day the pallet shroud was applied.

The day we initiated the MAP treatment, we received 3 pallets of packaged fruit. Fruit temperatures were checked to assure fruit were between 32 and 34°F. From each pallet we randomly selected and marked 4 boxes for future quality evaluation and 4 boxes for weight loss evaluation. For weight loss, the fruit were removed from the boxes and the tissue wraps and weighed, then carefully wrapped and packed again. Temperature and RH loggers were placed in the bottom of at least one of the weight boxes per pallet. The temperature and RH loggers were also placed in boxes on the control pallets. The boxes for the two covered pallets were placed onto a pallet fitted with a cardboard end cap and a fitted, plastic base sheet. The chosen weight loss and quality evaluation boxes were redistributed within the pallet that was to be covered with the pallet shroud. The pallet was covered with the shroud which was pulled down tight over the top of the pallet and tucked inside the base sheet. Then the bottom half of the pallet was wrapped with stretch wrap using a stretch-wrap machine up to mid-height of the pallet. The 8 boxes used for the control fruit were arranged on a separate pallet that was not covered. The treated and control pallets were immediately stored at 32 -34°F.

The treated and control pallets were stored for 10 to 15 weeks. The control and MAP pallets from the same harvest were stored for the same length of time and in the same cold room. The time of storage varied because some of the pallets were removed early due to observations of damage and the loss of cold room availability (Table 2).

The oxygen and carbon dioxide concentrations in the pallets were measured periodically during storage using Drager gas detector tubes. Ethylene concentration was also measured near the end of the storage period.

Table 1. Harvest date, treatment date and initial firmness of Bartlett pears covered with MAP.

Harvest date	**Location (County)**	**Packaging box type**	**Date Covered with Shroud**	**Weight of Fruit on Pallet**	**Treated Pallets**	**Initial Firmness[1] (lbs)**
7/23/05	Sacramento	Wrapped	7/26/05	1,960	1, 2, and control	17.0
7/27/05	Sacramento	Wrapped	8/2/05	1,960	3, 4, and control	14.3
8/1/05	Sacramento	Cosco	8/4/05	1,296	Cosco 1, 2, and control	15.3
8/23/05	Lake	Tight-fill	8/24/05	2,016	5, 6, and control	16.3
8/25/05	Lake	Tight-fill	8/29/05	2,016	7, 8, and control	16.3

[1]The firmness of a sample of 30 fruit was checked after the pallets were covered with MAP.

Quality evaluation

Fruit were evaluated for weight loss and quality. The weight loss was assessed the day we ended the treatment. Following storage, fruit were evaluated for external and internal quality immediately before ripening (day 0) and after 5 days of ripening at 68°F and 90 – 95% RH. A total of 30 fruit from each quality box to be evaluated from each pallet (120 fruit per pallet) were randomly chosen and split in 2 groups to be evaluated at day 0 and day 5 of ripening.

The fruit were evaluated for color, scald incidence and severity, decay severity, internal browning incidence and severity, marketability, percent soluble solids (before ripening only), titratable acidity (before ripening only), and flesh firmness.

The color and damage scales were as follows:

Color score: 1 = green; 2 = light green; 3 = light yellow; 4 = yellow (from CA Dept. Ag. Color chart).
Scald: 0 = none; 1 = slight (1-20%); 2 = moderate (21-40%); 3 = severe (>41%).
Decay and internal browning score: 0 = none; 1 = slight; 2 = moderate; 3 = severe.
Marketability: 0 = no damage; 1 = slight damage, but still marketable; 2 = not marketable

The fruit was considered unmarketable if the pears had slight to severe internal browning or decay.

Results

Pallet Shroud Conditions

The temperature within the pallet shrouds was expected to be higher than outside due to the heat of respiration from the fruit and the lack of ventilation with cold air. However, this was only seen in a few pallets. The largest difference in temperature was seen in pallets 1 and 3 where the pallets with shrouds had a higher temperature. However, for pallets 4, 5 and 7 and Cosco pallet 2, the shrouded pallets had a slightly lower temperature (Figures 1 & 2). There could also be some variability in the temperature sensors used. The temperature in the cold room increased from 30 to 33°F after the first two pallets had been in storage for 6 weeks and the temperature remained at 33°F for the remainder of the storage period for all of the pallets (Figures 1 & 2).

The relative humidity was also expected to be higher inside the pallet shrouds. However, this was only the case in 3 out of the 10 pallets (Figures 1 & 2). There is likely some variability among the humidity sensors as it is difficult to accurately measure relative humidity at levels greater than 90%, but there does not appear to be a large difference in relative humidity levels. Despite this, there was a large effect of the pallet shrouds on fruit weight loss. On average, the pallet shrouds reduced pear weight loss by 50 to 75% (Table 2).

The gas composition inside the pallet shrouds varied from pallet to pallet. For some pallets, the data indicate that the pallet shroud was not well sealed so that the carbon dioxide concentration only increased to 3 to 7% and the oxygen concentration remained at 10 to 18% (Figures 3 & 4). The pallet shrouds are designed to achieve 7% carbon dioxide and 13% oxygen. This pattern was seen in pallet 1, Cosco pallets 1 and 2, and pallet 8. For the Cosco pallets, it is important to note that the pallet shrouds used were not designed for use with such a small weight of fruit and this was certainly the reason for greatly reduced atmosphere modification. Pallet 1 came close to achieving the proper atmosphere and may have had a small leak in the shroud. Pallet 8 was clearly not well sealed.

These results point out the importance of using the proper pallet shroud for the amount of fruit on the pallet and using taking care with the proper technique in fitting and sealing the pallet shroud onto the pallet. In other pallets, the atmosphere levels fluctuated somewhat throughout the storage period with higher levels of carbon dioxide (5 to 13%) and moderate levels of oxygen (7 to 13%). Pallet 4 showed a sudden change in the atmosphere at week 8 indicating a puncture to the pallet shroud occurred at that time (Figure 3) resulting in a decrease in carbon dioxide and an increase in oxygen.

The ethylene concentration accumulated inside the pallet shrouds during storage. Just before the pallet shrouds were removed, the ethylene concentration was highest in the pallets from Sacramento which had been stored the longest, but was especially high in pallet 2 (Table 3). The reason for the very high ethylene in pallet 2 is unknown because this fruit was the most firm of all the pallets (Table 1). The lower ethylene concentration in pallet 1 which was from the same fruit lot as pallet 2 is indicative of a poorly sealed pallet as is also evidenced by the gas data (Figure 3). The Cosco 2 pallet and the four pallets from Lake County had about 50ppm of ethylene within the pallet shroud. Previous studies have shown that high levels of ethylene at temperatures of 34°F and higher can greatly reduce pear fruit quality. Modified atmospheres generally inhibit the effects of ethylene on fruit physiology.

Pear Quality and Condition

Upon removal from cold storage. Upon removal from cold storage, the overall appearance of all the fruit within the four quality boxes from each pallet was determined (Table 4). This quick look indicated a reduced incidence of senescent scald on the fruit stored in Lifespan pallet shrouds as compared with the control fruit. The incidence of decay was reduced in the Lifespan pallets in most cases, with the exception of Cosco 1 and 2 and pallet 8 (none of which had an effective modification of the atmosphere within the bag).

A closer evaluation was made of fruit randomly selected from each of four quality boxes. Thirty fruit were selected from each box and 15 were evaluated immediately after cold storage and 15 after 5 days of ripening. Immediately after cold storage, there was little effect of the pallet covers on skin color (Table 5). Pallets 5 and 6 and Cosco 1 and 2 were light green in color, but the remaining pallets had light yellow fruit upon removal from storage. Many of the fruit in the pallet covers had higher firmness than their control fruit, but this did not occur in every pallet (Table 5). Pallet 8 and Cosco 1 had lower firmness than the control as might be expected given little modification to the carbon dioxide and oxygen concentrations and slightly higher temperatures during storage. In many cases, those fruit from the pallet shrouds had higher titratable acidity and sometimes slightly higher soluble solids (Table 5).

There was generally less senescent scald on the fruit stored in pallet shrouds upon removal from cold storage, but there were two exceptions, pallet 1 and Cosco 2 where scald was higher in the covered pallet (Table 5). Neither of these pallets had effective atmosphere modification (Figure 3). There was no senescent scald upon removal from storage in pallets 5, 6, 7 or 8 that were only stored 10 or 11 weeks. Scald severity was either the same or lower in the covered pallets as compared with control fruit except in the Cosco pallets which had little atmosphere modification. Decay incidence and severity was generally lower in the fruit within the pallet shrouds with a couple of exceptions (Table 5).

Internal browning results when the fruit have been stored too long. The more mature the fruit at harvest and the higher the storage temperature, the faster internal browning and breakdown develops in storage. The incidence and severity of internal browning was generally the same or, more often, higher in fruit from the pallet shrouds immediately after cold storage (Table 5). This may be due to elevated temperatures or ethylene concentration within the shrouds. It is possible that some of the internal browning was due to carbon dioxide injury, especially for pallets 5, 6 and 7 that had internal browning but not senescent scald. The control fruit in these pallets had no internal browning, unlike the other pallets. These pallets also had the highest levels of carbon dioxide. The percentage of marketable fruit was variable among the pallets and control fruit. The lowest percentage was seen in pallets 2, 3 and 4 for both treated and control fruit. Pallets 3 and 4 had the softest fruit at harvest (Table 1).

<u>After ripening</u>. There was little difference in skin color between fruit from the pallet shrouds and control fruit (Table 6). Firmness remained higher in fruit from the pallet shrouds in most harvests, the exception being pallets 3 and 4. Scald incidence was higher in control fruit for pallets 2, 3 and 4, but was higher in the covered pallets for pallets 5, 7, 8 and Cosco 1 and 2 (Table 6). Scald severity was highest in the control fruit except in Cosco 1 and 2. Decay incidence was generally lower in the covered pallets with the exception of pallet 1 and Cosco 1 (neither of which had an effective modified atmosphere), but decay severity was more frequently higher in the covered pallets. Internal browning incidence and severity was higher in the control fruit of pallets 2, 3 and 4, but higher in the covered pallets for pallets 1, 5, 6, 7, 8 and the two Cosco pallets (Table 6). These data seem to indicate internal browning was mostly related to senescence and not carbon dioxide injury, as the greater internal browning was also seen in pallets where the atmosphere was not well modified (pallets 1, 8 and the two Cosco pallets) and there was less internal browning than in control fruit for highly modified pallets 2, 3 and 4. The percent of marketable fruit after ripening was highly variable

among harvest dates and treatments, but was higher for the fruit that were harvested later in the season and stored less time.

Conclusion

Our results with modified atmosphere pallet bags for Bartlett pears in 2005 were not so encouraging. However, there were a number of problems we encountered during this trial and a few mistakes that were made. First, the fruit obtained for the treatments were softer than desirable for long term storage or for modified atmosphere storage (although within a range considered acceptable by Amcor, manufacturer of the Lifespan pallet shrouds). The values we obtained for firmness at the time the treatments were begun were significantly lower than the values recorded by the packinghouse at the time of packing. We do not know the reason for this discrepancy, but assume it is due to variability in the manual firmness measurement techniques. Another factor was the increase in the storage room temperature after the first 6 weeks of cold storage from 30 to 33°F. Our previous work has shown that storage temperature has a significant effect on pear fruit quality after storage. Temperature also has an effect on fruit respiration rates and ability to tolerate modified atmosphere storage; however, the storage temperatures were also within the range considered acceptable by Amcor. The Coscol boxes were added to the test at the last minute. These pallets held about 50% less fruit weight than the pallet shrouds were designed to hold resulting in low carbon dioxide levels. The results also indicated that we did not achieve a tight seal of the pallet shroud in pallets 1 and 8. Because of issues with the quality of fruit from pallet 1 after 15 weeks and the impending loss of availability of the cold storage space we had been using, we decided to remove all the pallets from storage at the same time. This resulted in a range of storage times from 10 to 15 weeks which affected our ability to interpret any possible effects of the harvest date and fruit maturity at harvest on response to the treatment.

Despite these problems, the data generally show less decay and senescent scald and higher firmness in the fruit stored under pallet shrouds. I believe the results would be better if fruit closer to 17 pounds were used in these tests. Of course, it is also critical to use the correct pallet shroud for the amount of fruit on the pallet and to take care in installing the shrouds to ensure a good seal. Our results indicate additional work should be done before the California pear industry adopts pallet shroud technology. This technology has been successfully used in Washington; however, we continually learn that California Bartlett pears are very different from Washington Bartlett pears. I believe it is worthwhile to repeat this study in California, taking care to obtain fruit closer to the start of the harvest season, as there remains potential to realize storage benefits in enhanced quality maintenance without the expense of controlled atmosphere storage by using modified atmosphere pallet shrouds.

Table 2. Time of storage and percent weight loss of fruit following storage.

Pallet	Storage Time (weeks)	Percent Weight loss ±SD
1	14	3.8 ± 3.4
Control	14	4.0 ± 0.3
2	15	2.6 ± 0.8
Control	15	6.5 ± 2.2
3	14	2.1 ± 0.1
4	14	2.2 ± 0.1
Control	14	3.8 ± 0.3
Cosco 1	14	1.3 ± 0.1
Cosco 2	14	1.2 ± 0.1
Control	14	5.2 ± 0.2
5	11	0.0 ± 0.1
6	11	0.6 ± 0.4
Control	11	3.7 ± 0.6
7	10	0.5 ± 0.3
8	10	1.2 ± 0.1
Control	10	3.6 ± 1.1

SD = standard deviation

Table 3. Approximate ethylene concentration of covered pallets the day the treatment was stopped.

Pallet	Date analyzed	Ethylene (ppm)[1]
1	10/31/01	100
2	11/10/05	400 – 600
3	11/10/05	200
4	11/10/05	100
Cosco 1	11/10/05	50 – 100
Cosco 2	11/10/05	20 - 50
5	11/10/05	50
6	11/10/05	50
7	11/10/05	50
8	11/10/05	50

[1]The ethylene concentration (ppm) was measured using 20 – 1,200 ppm, Sensidyne, Precision ethylene gas detector tubes.

Table 4. Average scald and decay incidence of fruit within each of four boxes per pallet upon removal from cold storage.

Harvest date	**Location (County)**	**Pallet**	**Total No. fruits**	**Scald incidence (%)**	**Decay incidence (%)**	**Storage Time (weeks)**
7/23/05	Sacramento	2	110	3.2 ± 4.3	1.6 ± 0.9	15
		Control	110	22.7 ± 10.3	8.2 ± 0.0	15
7/27/05	Sacramento	3	110	0.0 ± 0.0	2.3 ± 1.9	14
		4	110	0.0 ± 0.0	2.7 ± 2.0	14
		Control	110	19.2 ± 3.4	5.5 ± 43	14
8/1/05	Sacramento	Cosco 1	11	0.0 ± 0.0	4.5 ± 5.2	14
		Cosco 2	11	0.0 ± 0.0	4.5 ± 5.2	14
		Control	11	0.0 ± 0.0	2.3 ± 4.5	14
8/23/05	Lake	5	88	0.0 ± 0.0	0.6 ± 1.1	11
		6	88	0.3 ± 0.6	1.0 ± 1.4	11
		Control	88	0.9 ± 1.1	3.1 ± 2.8	11
8/25/05	Lake	7	88	0.0 ± 0.0	5.4 ± 2.6	10
		8	88	0.0 ± 0.0	2.6 ± 2.5	10
		Control	88	0.0 ± 0.0	2.0 ± 1.1	10

± standard deviation

Table 5. Pear evaluation following cold storage and before ripening (day 0).

Pallet	Color[1]	Scald incidence	Scald severity[2]	Decay incidence	Decay[2]	IB incidence	IB[2]	Marketable (%)	SS	TA	Firmness (lbs)
1	2.6	63.3	1.4	6.7	2.0	28.3	1.3	63.3	12.0	0.18	11.8
Control	2.7	20.0	1.6	15.6	2.3	6.7	1.5	80.0	11.4	0.16	11.5
2	2.9	21.7	1.3	6.7	1.0	25.0	1.9	75.0	12.1	0.18	14.5
Control	2.8	36.7	1.6	13.3	1.4	8.9	1.2	65.0	11.5	0.14	10.1
3	2.7	16.7	1.6	0.0	0.0	37.8	2.7	71.7	12.8	0.19	11.7
4	2.5	13.3	1.3	6.7	2.0	20.0	2.3	78.3	12.1	0.18	12.5
Control	2.6	28.3	1.6	15.6	1.4	20.0	1.4	63.3	12.3	0.14	10.1
Cosco 1	1.9	10.0	2.0	5	1.0	5	2	90	12.8	0.14	13.1
Cosco 2	2.0	25.0	1.8	0	0.0	5	1	95	13.1	0.16	13.7
	1.7	10.0	1.0	15	1.2	5	1	95	13.1	0.17	13.3
5	1.6	0.0	0.0	0.0	0.0	11.1	1.8	91.7	13.5	0.18	16.9
6	1.7	0.0	0.0	6.7	1.0	30.0	2.0	70.0	12.7	0.17	16.4
Control	2.1	0.0	0.0	13.3	1.2	0.0	1.0	93.3	12.8	0.16	15.2
7	2.0	0.0	0.0	6.7	1.0	1.6	2.0	95.0	12.6	0.19	17.3
8	2.7	0.0	0.0	0.0	0.0	0.0	0.0	100.0	13.5	0.18	12.2
Control	2.3	0.0	0.0	6.7	1.0	0.0	0.0	95.0	15.3	0.18	15.6

[1]Color score: 1 = green; 2 = light green; 3 = light yellow; 4 = yellow.
[2]Scald, decay and internal browning score: 0 = none; 1 = slight; 2 = moderate; 3 = severe.
± standard deviation

Table 6. Pear evaluation following cold storage and 5 days ripening at 68°F.

Pallet	Color[1]	Scald incidence	Scald severity[2]	Decay incidence	Decay[2]	IB incidence	IB[2]	Marketable (%)	Firmness (lbs)
1	3.8	83.3	1.7	43.3	1.8	98.3	2.5	1.7	3.7
Control	3.6	81.7	1.5	38.3	1.6	93.3	2.5	5.0	2.9
2	3.3	40.0	1.7	8.9	1.0	55.0	2.2	40.0	3.4
Control	3.6	93.3	2.4	30.0	2.5	95.0	2.8	1.7	2.6
3	4.0	25.0	1.6	10.0	1.8	61.7	2.7	36.7	2.7
4	3.9	35.6	1.4	6.7	3.0	58.3	2.7	23.3	2.4
Control	3.9	83.3	2.3	20.0	2.7	93.3	2.8	5.0	3.2
Cosco 1	3.2	30.0	2.3	25.0	2.5	20	2.5	60	2.9
Cosco 2	2.6	50.0	1.6	0.0	0.0	0	0.0	85	3.2
	2.9	25.0	1.4	0.0	0.0	0	0.0	85	3.3
5	3.9	6.7	1.0	0.0	0.0	13.3	1.9	86.7	2.9
6	3.8	0.0	0.0	6.7	2.0	33.3	2.2	61.7	4.1
Control	3.2	0.0	0.0	13.3	1.8	0.0	0.0	63.3	2.3
7	3.6	13.3	1.5	0.0	0.0	1.5	1.5	93.3	2.0
8	3.8	6.7	1.5	8.4	1.5	21.7	2.1	73.3	2.1
Control	3.7	6.7	2.0	8.9	1.2	0.0	0.0	91.7	2.1

[1]Color score: 1 = green; 2 = light green; 3 = light yellow; 4 = yellow.

[2]Scald, decay and internal browning score: 0 = none; 1 = slight; 2 = moderate; 3 = severe.

± standard deviation

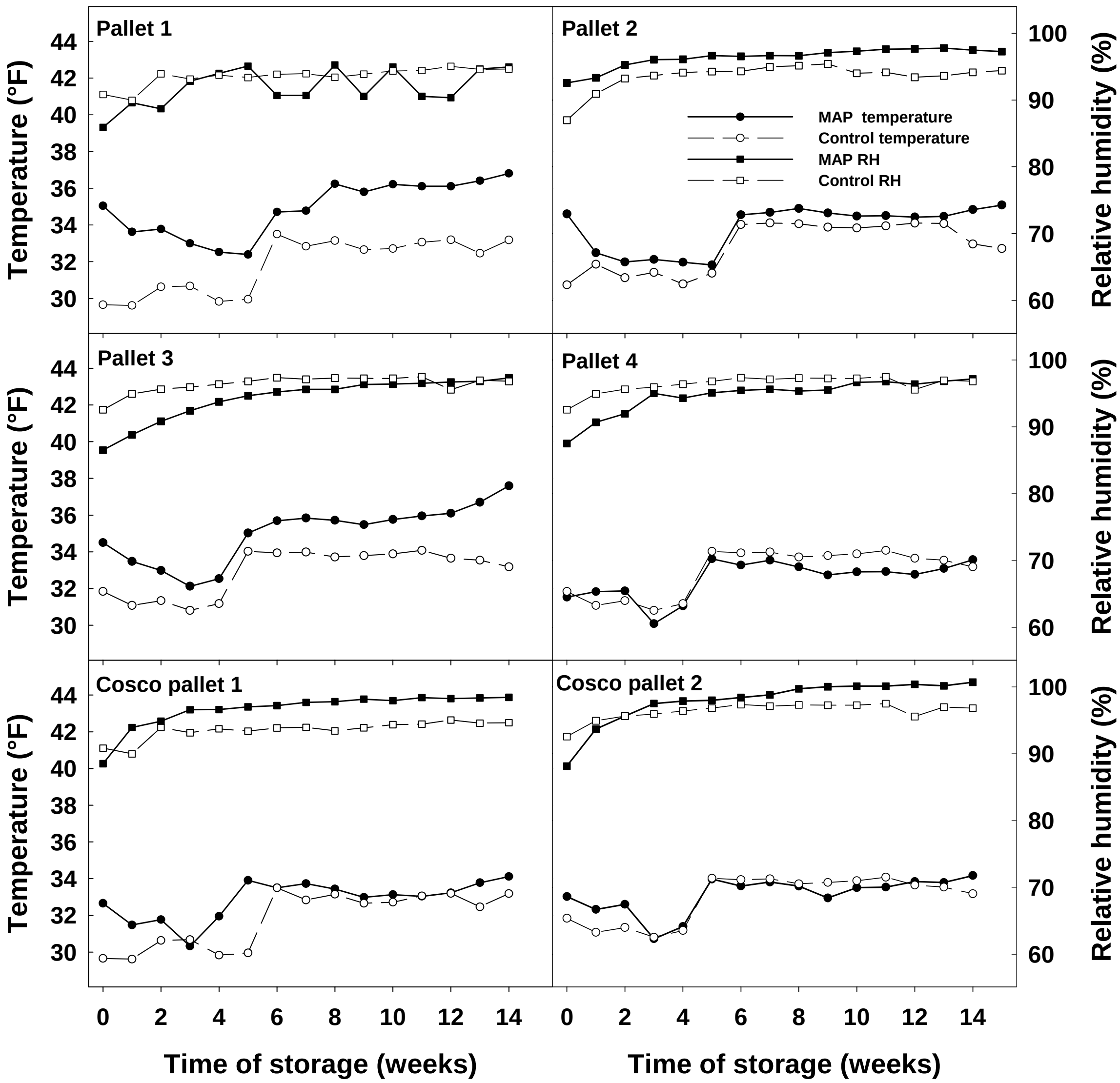

Figure 1. Temperature and relative humidity of Sacramento County fruit pallets covered with LifeSpan compared to pallets not covered with LifeSpan (control) during cold storage time (weeks).

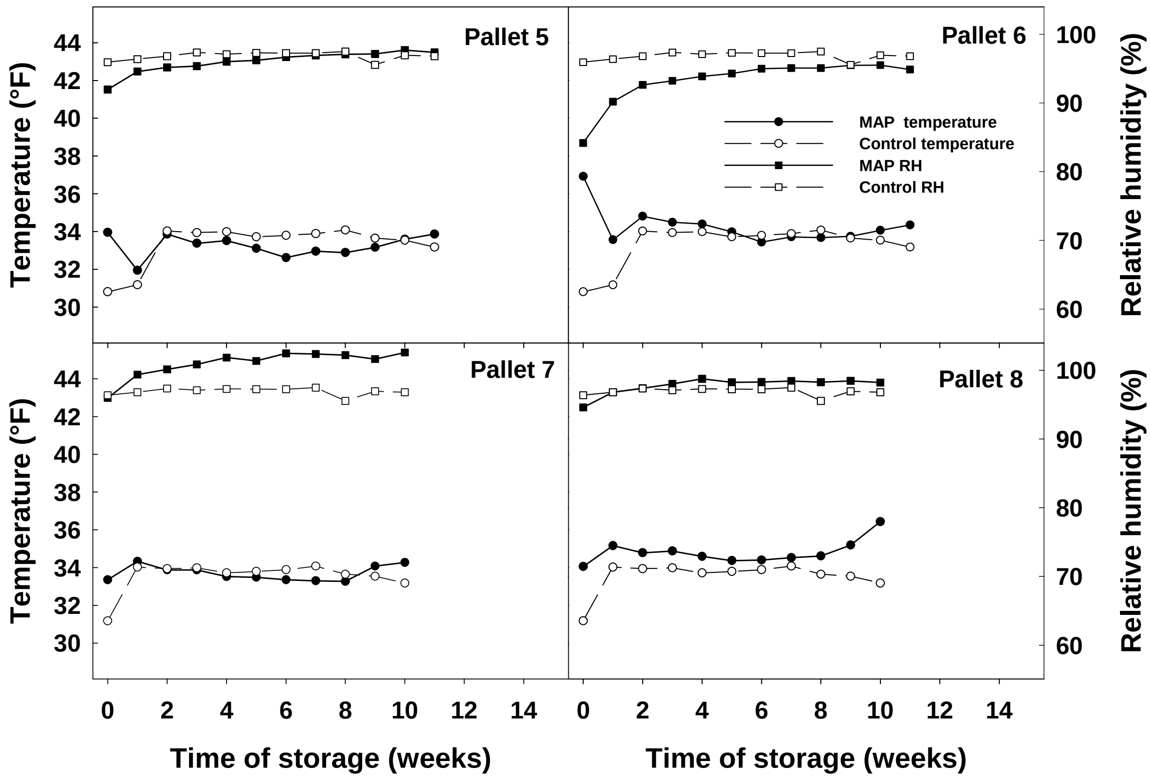

Figure 2. Temperature and relative humidity of Lake County fruit pallets covered with LifeSpan compared to pallets not covered with LifeSpan (control) during cold storage time (weeks).

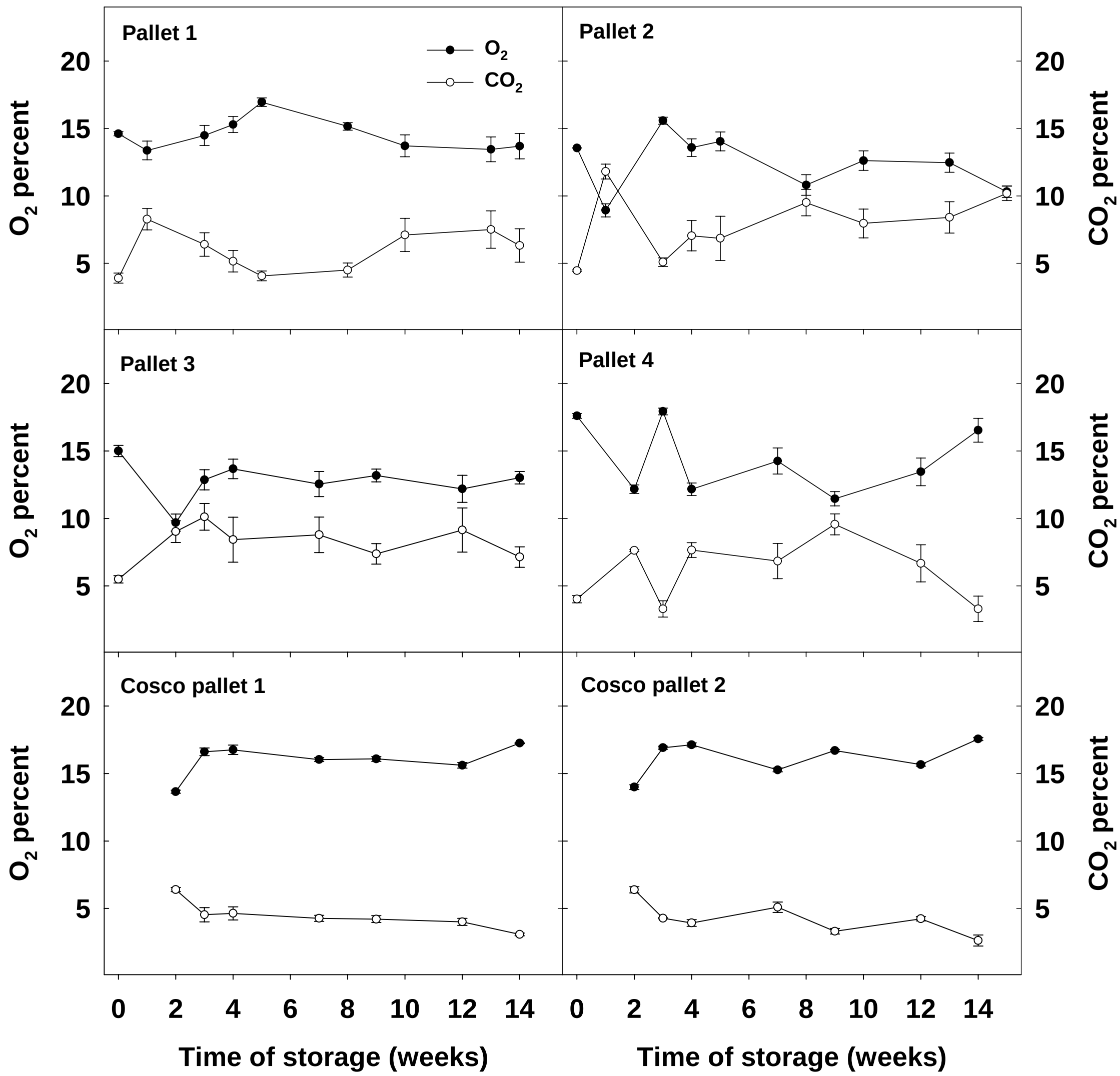

Figure 3. Carbon dioxide (CO_2) and oxygen (O_2) percent readings of fruit harvested in Sacramento County and covered with LifeSpan.

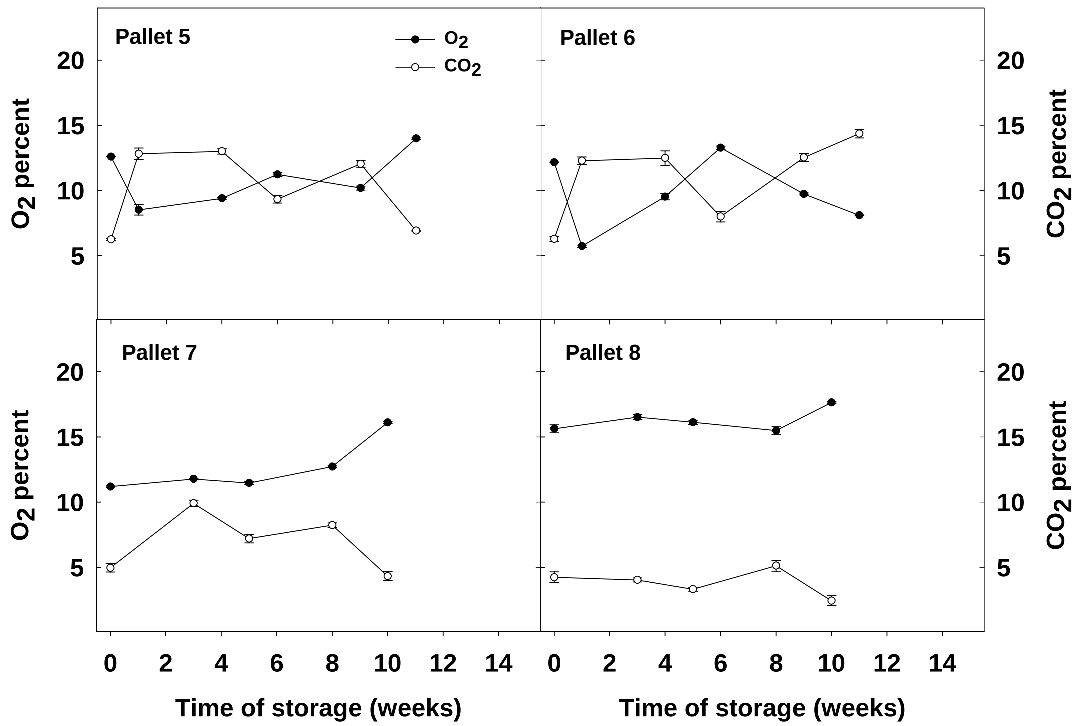

Figure 4. Carbon dioxide (CO_2) and oxygen (O_2) percent readings of fruit harvested in Lake County and covered with LifeSpan.