Research Updates

Influence of Place Packing or Tray Packing on the Cooling Rate of Palletized 'Anjou' Pears

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Summary. Tightly stacked pallets of wrapped, place-packed 'Anjou' pears cooled slower than those that were tray packed. Half-cooling times ranged from 2.0 to 15.7 days for wrapped, place-packed pears vs. 1.7 to 7.4 days for tray-packed pears. More time was required to remove heat from the middle than from the top or bottom of the pallets in both packaging systems; however, the difference in temperature between the middle and the top or bottom of the pallet was greater for a longer period of time when pears were wrapped and place packed. The large range in temperature within a pallet illustrated that a pallet is not a uniform unit. A change in how fruit are packed can dramatically change how fruit cool within a pallet. Accumulation of carbon dioxide and ethylene in slower-cooling boxes suggests that tray packing can enhance 'Anjou' quality by facilitating faster product cooling.

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Many factors need to be considered when determining an optimum packaging system for fresh commodities. The optimal package is inexpensive, recyclable, adaptable for high volume, and attractive to the customer; withstands stacking stresses; and protects the commodity from roller (vibration) bruising, impact bruising, compression damage, and excessive water loss (Mitchell, 1992). Packaging selection decisions are influenced by the value of the commodity, the cost of the packaging material and packaging system, and by customer preference. Small changes in package design can impact the rate of product cooling (Mitchell et al., 1972). Changes in a package need to be carefully evaluated before implementation to ensure that product quality will be maintained throughout the handling system.

More than 10 million boxes of 'Anjou' pears are hand packed each year in the northwestern United States into telescoping, two-piece, corrugated fiberboard boxes (13 × 10 × 20 inches) with hand holds. The fruit are wrapped with tissue and place packed in a specific pattern in a polyethylene-lined box. An alternative package that is becoming commercialized is a telescoping, two-piece, corrugated fiberboard box (13 × 12 × 20 inches) without hand holds. In this alternative system, the unwrapped fruit are placed on a pulp fiber tray. A polystyrene sheet is placed between tray layers and the fruit are enclosed in polyethylene lined boxes. Tray packed 'Anjou' pears with a polyethylene or polystyrene sheet on the top and bottom of the pears have been found to withstand simulated handling conditions well (Kupferman, 1993).

Standard industry practice in the Northwest is to wrap and place pack. The cartons are then palletized with air gaps between cartoons to facilitate cooling. The objective of this study was to evaluate the influence of wrapping pears in tissue and place packing or tray packing on the cooling rate of palletized 'Anjou' pears. To determine the effect of packing material on cooling rate, both pallets were tight stacked without gaps.

Materials and methods

Two pallets of 'Anjou' pears, size 70, were shipped from the Wenatchee, Wash., to Davis, Calif. One pallet contained tissue-wrapped, place-packed pears and the other contained tray-packed pears. Each pallet contained 49 boxes of pears. The tray-packed pallet arrived in Davis on 19 Apr. 1995. The place-packed pallet arrived on 12 Apr. 1996. Both pallets were part of a commercial apple and pear shipment. Both pallets were packed on the same day by Stemilt Growers Inc. (Wenatchee) in October 1995. After packing, Stemilt Growers Inc. stored the pallets in different rooms under similar conditions. Upon arrival to Davis, the pears from both pallets were visually similar. Fruit temperature upon arrival for both pallets averaged 2 °C (36 °F). The pallets were broken down on arrival and the boxes were stored at –1.1 °C (30 °F). Due to limited laboratory space, cooling rates were determined one pallet at a time. Pears were warmed to ≈20 °C (68 °F) by laying the individual fruit out on tables for 12 to 24 h, then repacked, and the boxes were palletized. The rebuilt pallet had seven levels of boxes and seven boxes per level. The pallet was squeezed tightly together and strapped horizontally without spacers between the boxes. The tray-packed fruit had one polystyrene sheet on top of the pears and nothing between the bottom of the pears and the paper tray.

Thermocouples were inserted 2 cm deep into two fruit located in one box on each level of the pallet (Fig. 1). One fruit was used to represent temperature at the periphery of the pallet and the other was used to represent temperature at the center of the pallet. The 14 thermocouples were calibrated before testing in ice water and at 35 °C (95 °F). Four temperature-recording devices (Sapac, Monitor Co., Modesto, Calif.) were placed in the pallet to confirm thermocouple data. The average of the 14 thermocouples at the time of pallet transfer to 0 °C (32 °F) was used as the initial fruit temperature to determine the 1/2 cooling time, the time required for the fruit temperature to cool to one-half of the difference between the initial fruit temperature and the storage room temperature.

The rebuilt pallet was transferred to a 0 °C (32 °F) room (ambient levels of carbon dioxide and ethylene) with an average air flow of 40 ft/min. The average room temperature during the place-pack test was 0.3 °C (32.5 °F) and during the tray-packed test it was 0.1 °C (32.2 °F). The place-packed pallet was cooled first, and cooling was terminated after 25 d when one thermocouple reading was below the 7/8 cooling temperature of 3 °C (37 °F). The tray-packed pallet test was terminated after 14 d when several thermocouples read below the 7/8 cooling level of 3.4 °C (38.2 °F). The tray-packed pallet was taller than the place-packed pallet so, in the cold room, the air coming off of the coil had to be diverted to provide the same air speed around both pallets.

The levels of carbon dioxide and ethylene inside a box within the pallet were measured throughout the storage period using a peristaltic pump (Buchler, Fort Lee, N.J.) to circulate the air from the center of the box to the outside for sampling, and then back to the box. The continuous flow rate was 1 mL·min^{-1}. Carbon dioxide and ethylene concentrations were monitored on the bottom, third, fifth, and seventh (top) level on the pallet in boxes containing fruit with thermocouples. Carbon dioxide was measured with a Horiba infrared CO_2 analyzer, and ethylene was measured by gas chromatography.

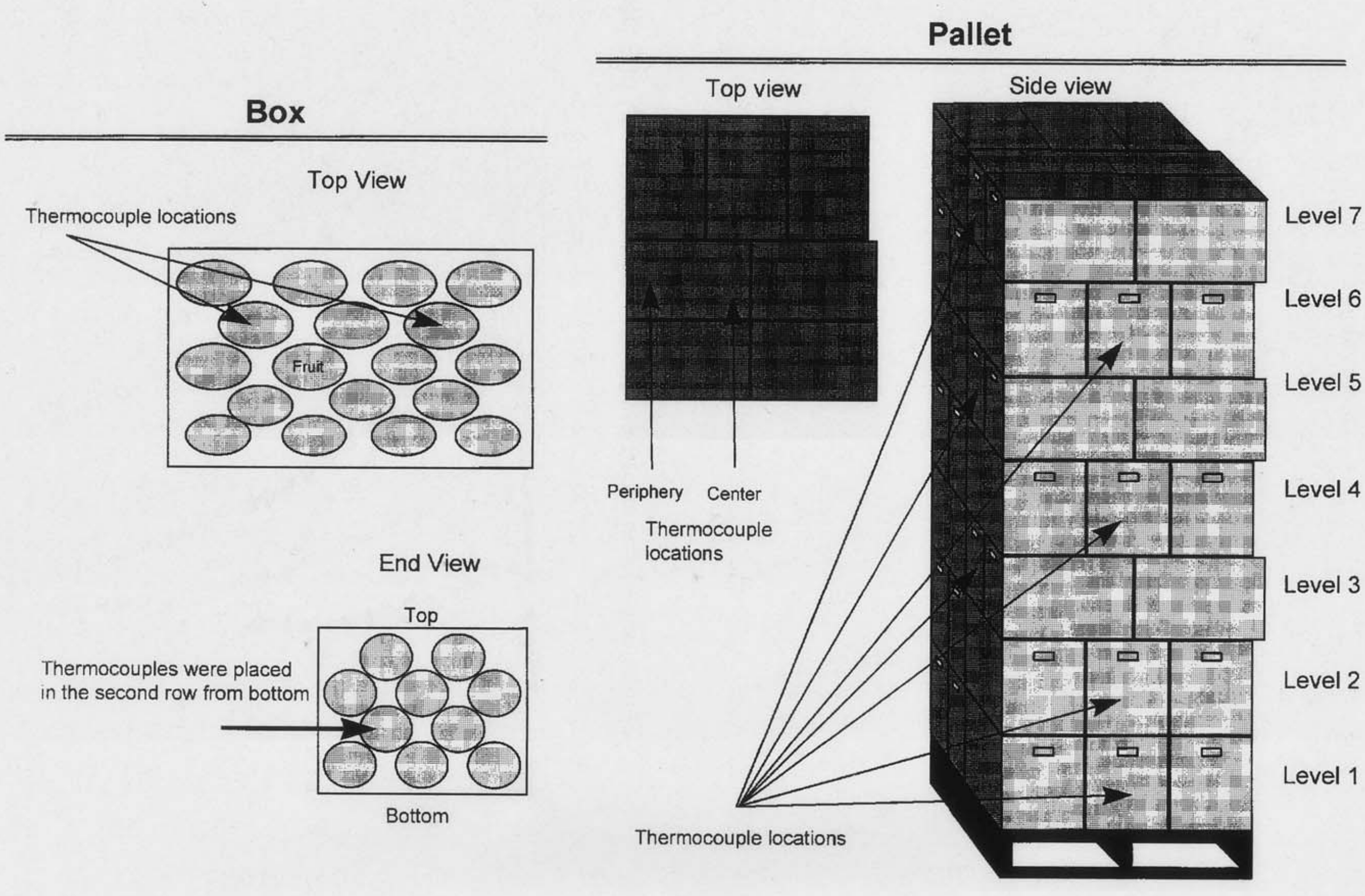
Firmness of the pear flesh was measured with a Univ. of California (UC) firmness penetrometer (Claypool and Fridley, 1966) using a 5/16-inch (7.9-mm) tip. The firmness of 50 fruit was evaluated before the pallets were rebuilt and cooled and once again after cooling. Differences in firmness within a pallet were determined by comparing the firmness of fruit in the thermocouple row on each level.

Results and discussion

The temperature data for the fruit in the center of the place-packed pallet, levels one, three, five, and seven, are shown in Fig. 2. The level-one box cooled fairly uniformly, with a small temperature differential between fruit at the center and fruit at the pallet periphery. Level one was the fastest-cooling level. Level five cooled the slowest and had the largest temperature differential between fruit at the center and fruit at the pallet periphery.

The temperature data for the fruit in the center of the tray-packed pallet, levels one, three, five, and seven, are also shown in Fig. 2. The level-one box cooled very fast and uniformly,

Fig. 1. Schematic of pallet design and thermocouple location within the pallet and box. Two thermocouples were placed in each box and one box per level was monitored.



with little difference between peripheral and central thermocouples. Levels three and five cooled the slowest and there was a larger temperature difference between the peripheral and central thermocouple locations. This temperature differential was less in the tray-packed than in the place-packed test.

The fruit temperature data (Fig. 2) show that the cooling rate is greater in the tray-packed system. The warming of the fruit after transfer to 0 °C (32 °F) is seen with the center thermocouple, place-packed levels 3 and 5. This contributes significantly to the time required to reach 1/2 cooling at those locations.

The 1/2 cooling times for both pallets (Table 1) show that the tray-packed pears cooled faster with the same pallet, box, and liner configurations as the place-packed pears. However, these data also show that both pallets did not cool uniformly and that cooling in the box is not uniform; this is most likely due to the lack of openings other than hand holds on the boxes.

The carbon dioxide concentration in the place-packed boxes was lowest in level seven (top) and highest in level three (Fig. 3). Carbon dioxide reached a high of 3.5% in levels one and three 16 h after transferring the pallet to 0 °C (32 °F). The ethylene level in the boxes initially was between 2 and 9 ppm. The ethylene concentration increased during the test and reached a high of just under 30 ppm in level three.

The carbon dioxide concentration in the tray-packed boxes was lowest in the bottom level, level one, and highest in level three (Fig. 3). Carbon dioxide reached a high of 3.0% in the box on level three soon after the test began. The ethylene levels in the boxes initially were between 13 and 22 ppm and increased in all box levels during the test to a high of 40 ppm in level three. The rapid drop in carbon dioxide and ethylene concentrations in level seven after day 10 is due to the loss of the air dam on the coil, which increased the air velocity around the top levels of the tray-packed pallet.

The firmness of the fruit after the cooling test is shown in Fig. 4, which represents the average firmness of the thermocouple layer (Fig. 1) in the box, for each of the seven levels. The firmness was measured after the cooling test was completed. Comparison between packing systems is not valid due to experimental design. The firmness data show the impact of slow cooling, with greater fruit softening occurring in the middle levels of both pallets.

Conclusions

The start temperature for the place-packed fruit was 2 °C (3.6 °F) higher than for the tray-packed fruit. The place-packed fruit were handled individually, while the tray-packed pears were warmed on the trays. The

Fig. 2. Temperature 2 cm into pear fruit. (A) At the center of the pallet in pallet levels 1 (bottom), 3, 5, 7 (top) with tissue wrapped: place-packed ● or ◆ or tray-packed pears. (B) Difference between fruit at the pallet center and fruit at the pallet periphery for tissue wrapped: place-packed ● or ◆ tray-packed pears.

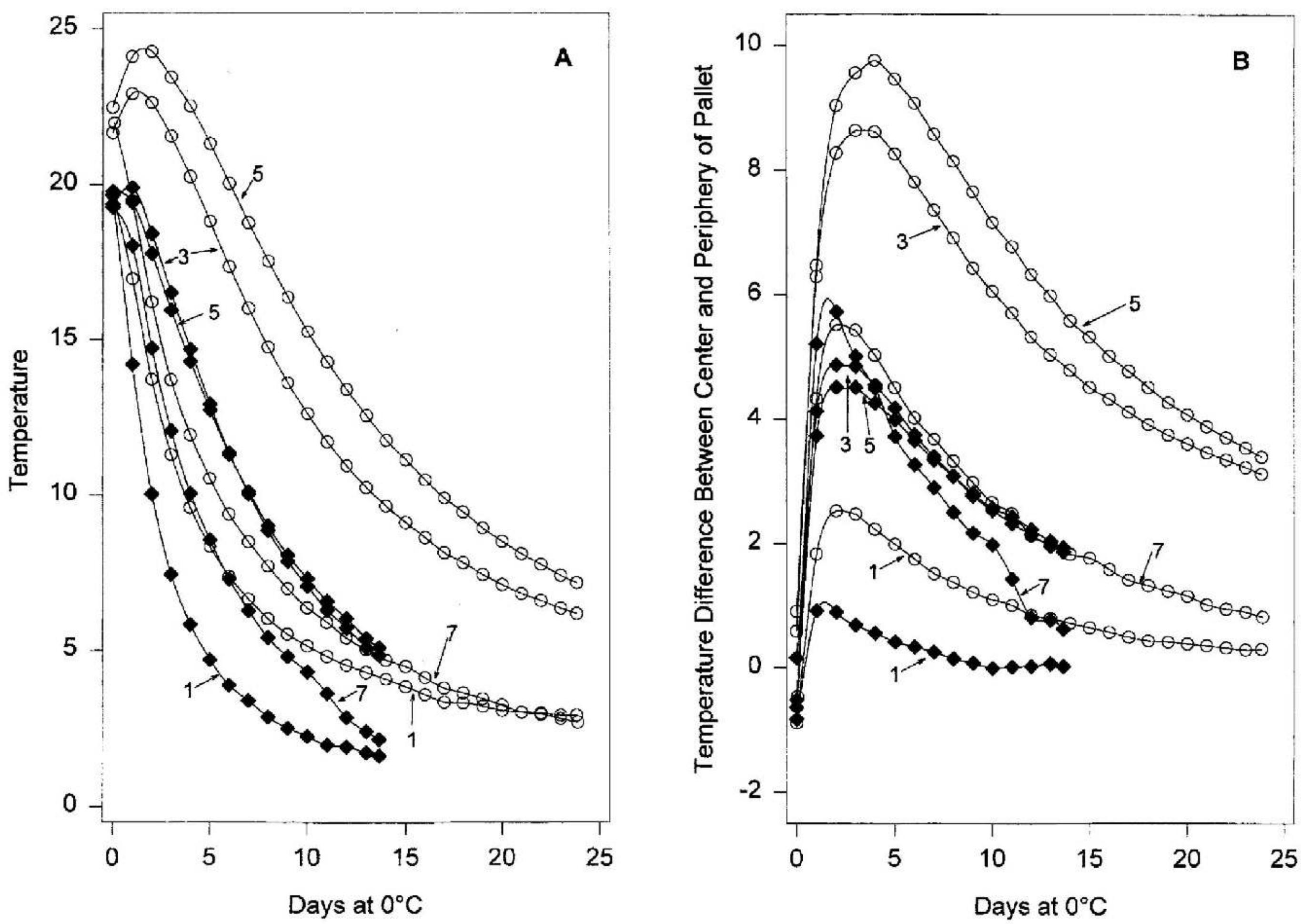


Table 1. Days required to reach the one-half cooling temperature ($T_{1/2}$)[z] for palletized 'Anjou' pears that were place packed or tray packed and stored at 0 °C with an air flow of 40 ft/min around the pallet surface.

	One-half cooling times (days)			
	Place packed[y]		Tray packed[x]	
Pallet level	Outside fruit	Inside fruit	Outside fruit	Inside fruit
1 bottom	2.1	3.3	1.8	2.1
2	4.9	8.7	3.4	5.5
3	4.9	12.4	4.3	7.2
4	7.0	15.0	4.6	7.2
5	6.4	15.7	4.2	7.3
6	7.0	13.0	4.1	7.4
7 top	2.0	4.9	1.7	4.2

[z]$T_{1/2}$ = (fruit starting temperature − storage room temperature) × 0.5 + storage room temperature.
[y]Start temperature = 21.6 °C (70.8 °F), Room temperature = 0.3 °C (32.5 °F), and $T_{1/2}$ = 10.9 °C (51.6 °F).
[x]Start temperature = 19.6 °C (67.3 °F), Room temperature = 0.1 °C (32.3 °F), and $T_{1/2}$ = 9.9C (49.5 °F).

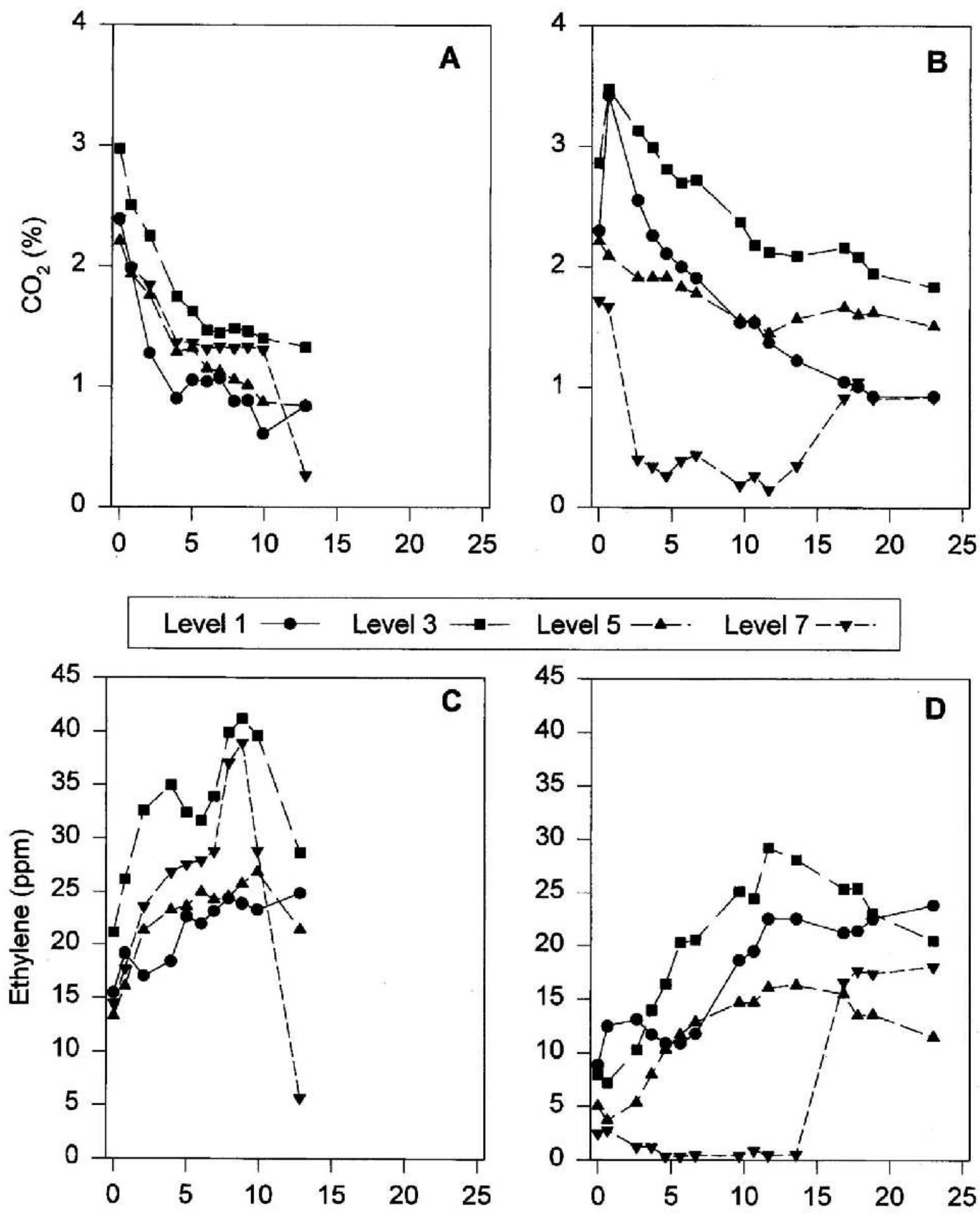


Fig. 3. Palletized 'Anjou' pear gas concentration within the box during storage at 0 °C (32 °F). (A) Carbon dioxide level, place-packed; (B) ethylene level, place-packed; (C) carbon dioxide level, tray-packed; (D) ethylene level, tray-packed.

time required to repack the boxes was greater for the place-packed pallet (9 h) than for the tray-packed pallet (4 h). The data clearly show that fruit temperature can increase during the first few days of cooling (Fig. 2). The greater time required to pack the place-packed fruit might explain the increased start temperature and wider initial range of temperatures (Fig. 2) due to temperature increases in the boxes after they were packed. Using the 1/2 cooling temperature to compare the cooling rates minimizes the difference in starting temperatures.

The data indicate that 1/2 cooling times of the tray-packed pears were as much as 50% faster than the place-pack fruited. Seven-eighths cooling is typically desired in most commercial cooling operations. Cooling curves resemble logarithmic functions, so 7/8 cooling is roughly three times the 1/2 cooling time (Guillou, 1960). This means that 7/8 cooling for the middle of the place-packed pallet would require 45 d at 0 °C (32 °F). In the tray-packed pallet, 7/8 cooling would require 21 d. While it is not expected that 'Anjou' pears would reach 20 °C (68 °F) during typical commercial packing, the fruit would still warm up significantly, and packing procedures such as use of heated air to dry surface wax will elevate pear temperatures (Drake et al., 1991). Regardless of the fruit temperature at packing, tray-packed pears in the center of the pallet will reach 7/8 cooling about two times faster than place-packed fruit. Box venting (≈5% of the surface area open) would speed up cooling rate of place-packed and tray-packed pears. Also forced-air cooling would significantly increase cooling rate, especially of the vented boxes.

The accumulation of carbon dioxide and ethylene in the pallet stack was very high. In pears, carbon dioxide can decrease the sen-

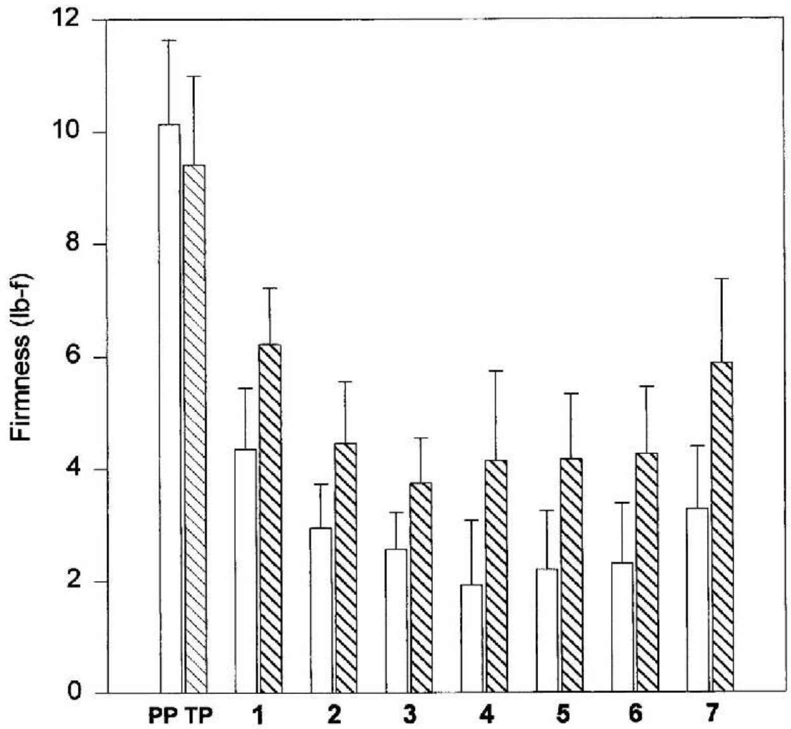


Fig. 4. Firmness of 'Anjou' pears initially after warming to 20 °C (68 °F) and after cooling in each of the seven pallet levels.

sitivity to ethylene, delaying ripening. However, high carbon dioxide concentrations (>10%) can lead to internal carbon dioxide injury, especially in the presence of oxygen concentrations <8%. Maturity at harvest influences sensitivity to carbon dioxide (Kader, 1989; Hansen, 1961). Storing warm palletized fruit in a controlled atmosphere potentially could cause the carbon dioxide and oxygen to reach injurious levels. The effect of air velocity around the pallet can be seen in Fig. 3. On day 10, the air dam fell off of the coil outlet allowing the air to hit the top of the pallet; this resulted in a rapid drop in gas accumulation in level seven (Fig. 3).

A greater accumulation of carbon dioxide and ethylene was associated with the slower cooling in the boxes located in the middle of the pallet. The gas concentration in the box could be influenced by three variables: fruit temperature, timing of the climacteric, and the decrease in the concentration gradient created by the neighboring boxes. The data clearly show that a pallet of either of these packing systems should not be viewed as a uniform unit.

Care must be taken when evaluating palletized fruit temperature. The pallets in this experiment clearly did not cool uniformly. Sampling fruit temperatures near the surface of the pallet will not give an accurate picture of what is actually taking place. These data also demonstrate the care that must be taken when adopting changes in packing systems. A simple change in how the fruit are packed can cause a dramatic change in how the fruit cool as a pallet. In this case, the simple change had a positive impact.

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