Conditioning Anjou Pears
Summary of Research Conducted by the WSU Tree Fruit Postharvest Laboratory

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An extensive series of trials was conducted on the 2008 and 2009 Anjou pear crops to determine how to improve the conditioning process to accelerate ripening to meet consumer expectations. This document summarizes those trials. The term 'pear' refers to Anjou pears. No experiments were done in our lab on other varieties. Funding was provided by the Pear Bureau, Washington State University and the Fresh Pear Committee

Supporting data from specific experiments are attached in the appendix.

1. How did pear consumers describe a quality pear?
Consumers in our tests expect that a high quality Anjou pear is between 2 and 4 lbf when consumed. They expect the pear flavor and aroma to be present and sweeter pears are preferred. Consumers want pears that are ready to eat within four days of time of purchase.

2. Were consumers willing to pay more for pears that they consider high quality?
Yes, the consumers in our tests are willing to pay more for pears that have been conditioned and are ready or close to ready to eat. This is especially true in the early marketing season. Pears that were soft, juicy and ready to eat within four days of purchase commanded a higher price premium than fruit that was hard and green.

3. Did all pears benefit from an ethylene conditioning treatment?
In our trials, ethylene conditioned pears ripened uniformly; more pears in a box ripened rapidly and softened to a uniform pressure. Pears that had not completed their 'chilling period' benefited by accelerated ripening after conditioning. Fruit that had completed their chilling period benefited less from ethylene conditioning than those treated earlier in the season.

4. How long is the chilling period for Anjou pears?
Various experiments have been done to determine chilling period for Anjou pears and each has come up with a different number. The chilling requirement is a function of the maturity of pear, in that fruit that was harvested later required a shorter chilling period. In one orchard we found that fruit harvested at 14 lbf required a longer chilling period than fruit harvested only three days later at virtually the same firmness. In this study, Anjou pears needed at least 35 days in cold storage before they ripened normally. Other studies suggest that Anjou pears need 60 days. Part of the problem is how 'ripe' is defined. Some pears can be of edible quality (flavor, juiciness, sweetness, and aroma) at higher firmness levels.

5. When the chilling period was not met, what was the best conditioning treatment?
Pears from some orchards ripened with edible quality when conditioned using the standard method of warming to 65 ºF and treating with ethylene for 24 hours, while fruit from other orchards needed additional time exposed to ethylene. As the storage season progressed, there were more lots of fruit that ripened with quality after ethylene conditioning for 24 hours, or ripened without conditioning.

However, even when the chilling requirement had been met and fruit were capable of softening after cold storage, ethylene improved the uniformity of firmness and stimulated aroma volatile production. It took less ethylene to stimulate softening than to stimulate aroma production.

Fruit harvested early, as in fruit harvested for long-term storage but diverted to early season sales, took a longer time to be conditioned than those harvested later, in some cases as much as four days or more to condition with ethylene.

An additional factor in deciding on the length of conditioning is the firmness required to ship the fruit long distances. A current commercial requirement set by distribution centers is that fruit should be 8 lbf or greater on receipt to acceptable. In this case, the fruit needs to be at or above this firmness when shipped. Yet consumers demand fruit that soften within 4 days of purchase to 4 lbf or less. Conditioning technicians must be aware of this requirement.

6. Did pears respond uniformly to conditioning?

No, fruit from different orchards responded differently to the same conditioning regime, even though the initial firmness might have been the same. It is not well understood why this happens, but fruit from some orchards did not respond to a specific conditioning treatment while fruit from other orchards softened rapidly. Softer fruit at time of initiation of conditioning softened faster than firmer fruit.

7. What was the effect of fruit and treatment temperature during conditioning on speed of ripening?

In our experiments there was no clear pattern in fruit firmness immediately after conditioning or after ripening when the pulp or air temperatures were between 60 and 70 ºF during conditioning. In some lots there was no difference and in others the difference was slight.

8. What was the effect of post-conditioning temperature on ripening?

In our experiments holding fruit at warm temperatures for longer periods after ethylene treatment accelerated ripening. Fruit that were cooled immediately after conditioning ripened more slowly than when the fruit were held at warm temperatures for a longer period after conditioning.

9. How much firmness was lost during conditioning and shipping?

In general, fruit that started firm (above 12 lbf) lost very little firmness during conditioning and transport when conditioned with ethylene for 1 day. The longer the conditioning period the more firmness was lost.

In one experiment we obtained fruit from 16 orchards that were warmed for 24 hours, conditioned with ethylene for 1 day (65 ºF) and placed in cold storage. The initial firmness of the 16 orchards ranged from 13.3 to 10.0 lbf. Following conditioning and 7 days simulated transport (34 ºF), fruit from 50% of the orchards were above 8 lbf. Some of the lots lost virtually no firmness and some lost over 5 lbf. Those that lost the most firmness were initially (prior to conditioning) 10 to 12 lbf. Those that lost the least firmness were initially above 12 lbf.

When fruit from these orchards was conditioned for 2 days in ethylene, 31% of them were above 8 lbf after simulated transport for 7 days.

10. Did the concentration of ethylene influence the speed of ripening after conditioning?

Two lots of pears were warmed for 24 hours then conditioned with one of two concentrations of ethylene (20 and 200 ppm) for 1 day. In fruit from one orchard, the higher ethylene treated fruit were slightly less firm and more yellow after ripening. In contrast, there was no effect of the different ethylene concentrations on a second lot of fruit.

11. What were the differences in response in fruit packed in polylined hand wrapped boxes vs. Euro boxes

In our experiments, ethylene penetrated both polylined hand-wrapped boxes and unlined Euro boxes equally. In the polylined boxes the carbon dioxide rose more rapidly than in the Euro boxes, although the oxygen levels were not significantly different. There was no difference in fruit quality. The challenge with hand-wrapped boxes was uniformity of temperatures. In hand-wrapped boxes the fruit warmed and cooled far more slowly than in the Euro boxes, resulting in uneven ripening when the temperature differences of the fruit in the box were large.

12. Did soluble solids or acidity change during conditioning and ripening?

There were insignificant changes in soluble solids and acidity during conditioning and ripening. What did change was the firmness of the fruit and presence of aroma volatiles which gives the pear its characteristic flavor (and possibly the perceived sweetness of the fruit). In some cases fruit may be soft but lacking in aroma volatiles.

13. What was the relationship of price and quality in local markets?

We sampled Anjou pears in six local supermarkets in Wenatchee on October 14, 2009 and allowed the fruit to ripen for 5 days. It was evident that there was no relationship between price paid for the fruit and initial or ripe firmness. Prices ranged from $0.80 to $1.99/lb. Pears purchased at $0.80 and $1.00/lb remained hard after ripening. Pears purchased at $0.98/lb were soft and ripened well. Pears purchased for $1.40 were hard and ripened well. Pears purchased for $1.20 and $1.99 were below 4 lb at time of purchase.

14. What was the effect of SmartFresh on Anjou pear conditioning and ripening?

It is well known that the application of SmartFresh at the same concentration as used on apples (1 ppm) does not allow Anjou pears to soften even after a long storage duration. Scald is inhibited, but the fruit will not soften.

Commercial experience with SmartFresh on Anjou pears is limited but there have been some trials using parts per billion levels of SmartFresh. We obtained samples from one trial on April 9th, 2009 that had been treated with SmartFresh at harvest and stored until in CA in bins until April 8th, 2009 then packed into Euro cartons. We applied six different conditioning methods (including a non-conditioned control) to this fruit to compare response. Pears that were conditioned with the longest time in ethylene (warm for 24 hours, ethylene for 48 hours, warm for 24 hours) ripened the fastest; these pears were 4 lbf after only 2 days ripening. SmartFresh treated pears that were not conditioned took 5 days of ripening to soften to 4 lbf. Unfortunately, there were no samples that had not been treated with SmartFresh for comparison.

Conclusions:

It is my considered opinion based on this research, additional studies and the literature that:

- Ethylene conditioning provides a more uniform pear that softens more rapidly.
- Non-conditioned fruit at the start of the season are not acceptable to consumers.
- Effective ethylene conditioning should be required for <u>all</u> early season sales.
- Conditioning regime should be based on firmness prior to conditioning. Firmer fruit need more time in ethylene conditioning.
- Non-vented boxes and place-packed fruit will not achieve uniform temperatures. This will hinder ethylene response and reduce its effectiveness.
- Distribution centers and retailers need to learn to accept conditioned fruit. Conditioned fruit should be identified on retail shelves with a unique sticker.

CONDITIONING ANJOU PEARS: SUMMARY OF RESEARCH CONDUCTED BY THE WSU TREE FRUIT POSTHARVEST LABORATORY

APPENDIX – INFORMATION ABOUT SPECIFIC EXPERIMENTS

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How did pear consumers describe a quality pear?

An experiment was conducted in October 2008, December and March 2009 to determine how consumers describe quality in Anjou pears.

Consumer Trial 1—Pears That Had Not Met Their Chilling Requirement
Anjou pears from a single grower lot harvested between Sept 15th and Sept 21st were packed into Euro boxes with plastic trays by a commercial packer. The pears were obtained on Sept 29th so they had not received sufficient time in storage to have completed their chilling requirement. Fruit quality was evaluated at time of receipt, with the pears averaging 13.4 lbf with a color rating of 4.8 on a 1 to 10 scale (1 = dark green to 10 = yellow).

There were four conditioning treatments for the consumer trials in Portland; ethylene conditioning for 2, 4, or 6 days, or warm air conditioning for 7 days. Conditioning was done at 65 ºF using an Ethy-Gen catalytic ethylene generator and Ethy-Gen II concentrate (generator and concentrate from Catalytic Generators LLC, Norfolk, VA). The conditioning room averaged 131 ppm ethylene over the 6-day conditioning period.

Following conditioning, all fruit was returned to cold storage (33 ºF) for 48 hours to simulate transit to retail market. Three days prior to consumer evaluation all fruit was removed from cold storage and held at 70 ºF until testing.

Consumer Trial 2—Pears That Had Met Their Chilling Requirement (Mid-Season)
Anjou pears from a single grower were packed into Euro boxes with plastic trays by a commercial packer. Pears were obtained on November 13th and fruit quality was evaluated at time of receipt. The pears averaged 12.9 lbf with a color rating of 4.9 on a 1 to 10 scale (1 = dark green to 10 = yellow).

There were four conditioning treatments for the consumer trials in Portland; ethylene conditioning for 1, 2, or 4 days, or warm air conditioning for 5 days. Conditioning was done at 74 ºF in shroud covered box pallets using Ethylene Release Canisters (ERCs) (Balchem Corporation, New Hampton, NY). The conditioning treatments reached at least 50 ppm ethylene within 6 hours in the shrouds.

Following conditioning, all fruit was returned to cold storage (33 ºF) for 72 hours to simulate transit to retail market. Two days prior to consumer evaluation all fruit was removed from cold storage and held at 70 ºF until testing.

Consumer Trial 3—Pears That Had Met Their Chilling Requirement (Late-Season)
Anjou pears from a single grower lot harvested between Sept 27th and Sept 29th were packed into Euro boxes with plastic trays by a commercial packer. The pears were obtained on March 16th. Fruit quality was evaluated at time of receipt, with the pears averaging 12.6 lbf.

There were five conditioning treatments for the consumer trial in Portland: conditioning for 1 day with ethylene, 1 day ethylene plus 1 day in warm air, 1 or 2 days in warm air and 5 days ripening (no conditioning). Conditioning was done in shroud covered box pallets using ERCs (Balchem Corporation, New Hampton, NY). The conditioning treatments reached at least 50 ppm ethylene within 6 hours in the shrouds.

Following conditioning, all fruit was returned to cold storage (33 ºF) for 7 or 8 days to simulate transit to retail market. Three days prior to consumer evaluation all fruit was removed from cold

storage and held at 72 ºF until testing. The ripening only treatment was removed from cold storage 5 days prior to consumer evaluation and held at 72 ºF until testing.

Consumer Evaluations:
Consumer evaluation occurred at the Food Innovation Center, Oregon State University, Portland Oregon. Consumers were recruited via media advertisements, phone and email from the Portland Metro area for test participation at the Food Innovation Center. Qualification criteria for participation were: the consumers fall between the ages of 24 to 65 yrs, they have purchased fresh pears in season at least twice in the past month, 75 to 80% females, 20 to 25% males, at least 70% Caucasian, annual household income of 25K or over and at least a college degree. A panelist incentive of $25 was paid to participants of the consumer taste test.

Consumers were seated in individual testing booths under white lighting for testing. Sensory data were collected using a computerized data collection system utilizing Compusense® software. Testing began at 10am and 10 consumers were tested every 60 minutes until 4pm for a total of 12 sessions (120 consumers) over two days. Each consumer was served one-third of a pear; the rest of the pear was used for firmness and soluble solids testing on the same day of the consumer evaluation. Each sample was coded with randomized 3-digit numbers, served on 8-inch white plates and presented to the consumers on plastic trays. Each product was randomized and represented an equal number of times in the presentation design to prevent order effects. The pears were served monadically and rated for Overall Liking, Pear Flavor, Sweetness, Juiciness, Firmness, Texture and Purchase Intent. Consumers then ranked the pears for overall preference and were asked a series of marketing and demographic questions. Consumers also answered a number of comment questions.

Results Summary:
Consumers indicated that the main reasons for liking the pears were juiciness and sweetness. Only 17% indicated that firmness was a reason for liking (Table 1). Reasons for disliking included lack of pear flavor, too hard and gritty texture. Consequently consumers do not like hard pears but if the pears are less hard then juiciness and sweetness are critical parts of reasons for liking.

Drilling further into reasons consumers liked pears, we asked them to score components of flavor and texture as generated by the conditioning treatments used in this experiment (Tables 2 through 4). These components included pear flavor, sweetness, juiciness, firmness and texture as well as overall liking. In October, fruit conditioned for 6 days in ethylene scored the highest (Table 2). This fruit had the highest score in each of the flavor and texture components. When we compared the actual soluble solids and firmness with these scores we determined that the lowest soluble solids and lowest firmness fruit ranked highest. At first glance the soluble solids ranking and what people listed as reasons for liking did not conform. However, there was little difference in soluble solids between the treatments within each trial.

When asked to give the reasons they did not buy pears, consumers overwhelmingly chose the option that pears “don’t ripen properly and then go bad” (36%) (Table 5).

In summary, consumers want Anjou pears to eat that are ripened to about 2 lbf and have high soluble solids, high juiciness and strong pear flavor. Firmness is not the only attribute consumers use to judge quality; they also want pears that will ripen in 4 days or less.

Table 1. Reasons given by consumers for liking and disliking pears; three trials at OSU Food Innovation Center. Sweetness and juiciness were the most common reason for liking, and lack of flavor was the most common reason for disliking the pears.

	Reasons for Liking/Disliking Fruit		
	Trial 1, Oct. 2008	**Trial 2, Dec. 2008**	**Trial 3, Apr. 2009**
Reasons for Liking			
Juiciness	**42%**	23%	11%
Sweetness	35%	**42%**	**56%**
Firmness	17%	21%	13%
Tartness/sourness	3%	5%	8%
Other	3%	8%	9%
Smell/aroma	1%	0%	3%
Reasons for Disliking			
Lack of flavor	**33%**	**35%**	**43%**
Too hard	29%	18%	8%
Gritty texture	16%	13%	11%
Too soft	7%	14%	3%
Lack of sweetness	5%	2%	8%
Too tart or sour	4%	7%	16%
Lack of juiciness	4%	6%	3%
Other	2%	3%	4%
Not tart or sour enough	0%	1%	2%
Skin color	0%	1%	3%

To further define the target consumer's expectations they were asked how long they would be willing to wait for pear to ripen after purchase. Their response was resoundingly 4 days or less.

Days to Ripen	Dec. 2008 Test	Apr. 2009 Test
1 to 2	36%	27%
3 to 4	54%	58%
5 to 6	10%	15%

Table 2. Consumer liking scores for six Anjou pear attributes and pear quality measurements for each treatment; consumer sensory trials at the OSU FIC, Portland Oregon, **October 15-16, 2008**. Scale for liking is 1 =dislike extremely to 9 = like extremely.

	Consumer Liking Scores*							Pear Quality	
Treatment	**Overall**	**Pear flavor**	**Sweetness**	**Juiciness**	**Firmness**	**Texture**	**Ranked First****	**Soluble solids (%)**	**Firmness (lbf)**
6 day ethylene	7.48 a	7.46 a	7.11 a	7.95 a	6.97 a	7.26 a	74%	14.5 b	2.23 d
4 day ethylene	6.33 b	6.43 b	5.71 b	5.82 b	6.38 a	6.03 b	17%	14.6 b	3.46 c
2 day ethylene	4.49 c	4.82 c	3.93 c	3.17 c	4.96 b	4.13 c	2%	14.6 b	6.11 b
7 day air	4.33 c	4.74 c	3.73 c	2.47 d	4.24 c	4.08 c	7%	14.9 a	11.13 a

Scale for liking is 1 =dislike extremely to 9 = like extremely

* Scale for sweetness/juiciness is 1 =not sweet/juicy to 9 = ideally sweet/juicy

** Percentage of fruit in each treatment ranked first ("best")

Table 3. Consumer liking scores for six Anjou pear attributes and pear quality measurements for each treatment; consumer sensory trials at the OSU FIC, Portland Oregon, **December 9-10, 2008**.

Treatment	Consumer Liking Scores*						Ranked First**	Pear Quality	
	Overall	Pear flavor	Sweetness	Juiciness	Firmness	Texture		Soluble solids (%)	Firmness (lbf)
4-day ethylene	7.46 a	7.47 a	6.83 a	7.57 a	6.62 a	6.88 a	50%	15.1 a	2.47 c
2-day ethylene	6.13 bc	6.03 bc	5.06 c	4.97 c	6.17 ab	5.94 b	16%	14.7 bc	4.56 b
1-day ethylene	5.58 c	5.73 c	4.34 d	3.67 d	5.65 b	5.23 c	11%	14.5 c	6.71 a
5-day air	6.42 b	6.45 b	5.92 b	6.43 b	5.89 b	5.82 bc	23%	14.8 b	2.75 c

Scale for liking is 1 =dislike extremely to 9 = like extremely
* Scale for sweetness/juiciness is 1 =not sweet/juicy to 9 = ideally sweet/juicy
** Percentage of fruit in each treatment ranked first ("best")

Table 4. Consumer liking scores for six Anjou pear attributes and pear quality measurements for each treatment; consumer sensory trials at the OSU FIC, Portland Oregon, **March 31–April 1, 2009**.

Treatment	Consumer Liking Scores*						Ranked First**	Pear Quality	
	Overall	Pear flavor	Sweetness	Juiciness	Firmness	Texture		Soluble solids (%)	Firmness (lbf)
1-day air	6.2 a	6.0 abc	5.0 b	5.6 b	6.3 a	6.1 ab	17%	14.0	3.9
1-day ethylene	6.1 a	5.8 c	5.2 b	5.6 b	6.2 a	5.8 b	6%	13.9	4.0
2-day air	6.6 a	6.6 a	6.0 a	6.8 a	6.6 a	6.7 a	30%	14.1	3.1
1-day ethylene + 1-day air	6.6 a	6.4 ab	6.1 a	6.7 a	6.7 a	6.6 a	32%	14.0	3.1
5-day ripening	6.0 a	5.9 bc	5.3 b	5.8 a	6.2 a	5.8 b	16%	13.9	3.4

Scale for liking is 1 =dislike extremely to 9 = like extremely
* Scale for sweetness/juiciness is 1 =not sweet/juicy to 9 = ideally sweet/juicy
** Percentage of fruit in each treatment ranked first ("best")

Table 5. – Reasons given by consumers for NOT buying pears, **March 31–April 1, 2009**.

Why don't you buy pears	Trial 3, Apr. 2009
Don't like the flavor	2%
Don't like the texture	3%
Not ripe/ready to eat	7%
Don't ripen properly and then go bad	36%
Have a preference for other fruit	22%
Too expensive	12%
Other	20%

Were consumers willing to pay more for pears That They Consider High Quality?

In October 2008 we asked each consumer to compare prices for each of a series of pears they tasted. Consumers were willing to pay $1.75/lb for the best pears (6-day ethylene) served in October but would only pay $1.06/lb for pears they rated as the worst (7-day air), a $0.69/lb difference (Table 6).

We repeated the work in December 2008 and April 2009 with pears that had completed their chilling requirement. The difference in price consumers were willing to pay (best pears compared to worst pears) fell to $0.66/lb in December and $0.30/lb in April.

The base price to calculate premiums was based on phone surveys of the price of Anjou pears in supermarkets in the greater Portland metro area one week prior to each trial. The base price in October was $1.49/lb, December was $1.83/lb and April was $1.74/lb.

Table 6. Willingness-to-pay for pears under different conditioning treatments; October 2008, December 2008 and April 2009 experiments.

	Days in ethylene				**Days in warm air**				**1-day eth + 1-day air**	**Ripe Only**
	1 day	**2 day**	**4 day**	**6 day**	**1 day**	**2 day**	**5 day**	**7 day**		
October 15-16, 2008										
Willingness-to-pay (per lb)		$1.19	$1.53	$1.75				$1.06		
December 9-10, 2008										
Willingness-to-pay (per lb)	$1.55	$1.54	$2.20				$2.00			
March 31 – April 1, 2009										
Willingness-to-pay (per lb)	$1.60				$1.68	$1.88			$1.88	$1.58

Did all pears benefit from an ethylene conditioning treatment?

In early November 2009 fruit were obtained from five different packinghouses, representing a total of 16 different orchards. The fruit were conditioned in ethylene for 1 day or 2 days; conditioned in warm air for 2 days or ripened without conditioning. All fruit was ripened for 5 days (Figure 1). The firmness of the ethylene treated fruit was lower than fruit that had not been conditioned. The variability in firmness of the fruit treated with ethylene was much less than the variability of the fruit treated in warm air or not conditioned.

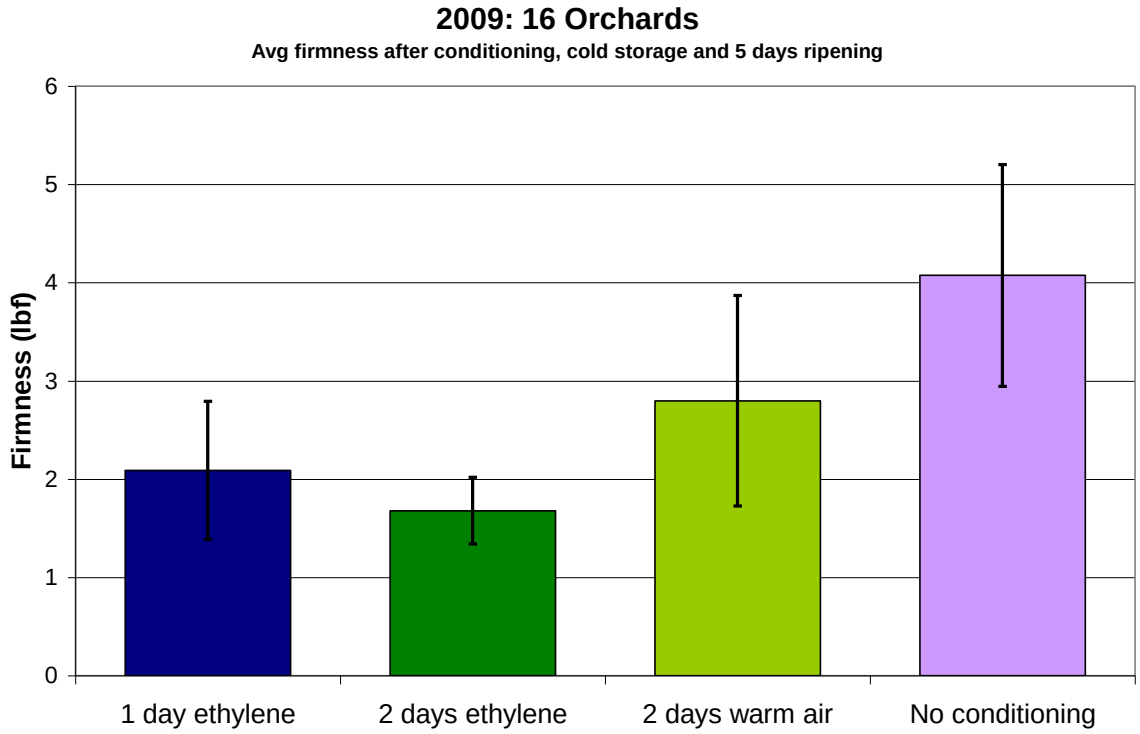


Figure 1. Comparison of average firmness after conditioning with ethylene (1 and 2 days), conditioning for 2 days in warm air and not conditioned. Fruit was ripened for 5 days.

How long is the chilling period for Anjou Pears?

A key to effective conditioning is the ability of the conditioning technician to predict the response of a lot of pears to ethylene treatment. It is the belief of some in the industry that fruit that is less firm can be conditioning for a shorter period of time. One method of obtaining fruit that is less firm is to delay harvest. To determine the effect of delaying harvest on the response to conditioning, we tested whether fruit held longer on the tree would require a shorter chilling period than fruit from the same orchard harvested later. We harvested fruit sequentially within the commercial harvest window and held it at 34 ºF, removing samples weekly and testing the edibility of the fruit after ripening the fruit at room temperature for 5 days.

Firmness of the fruit at harvest averaged from 14.1 lbf dropping to 11.8 lbf after delaying harvest for 14 days (Figure 2).

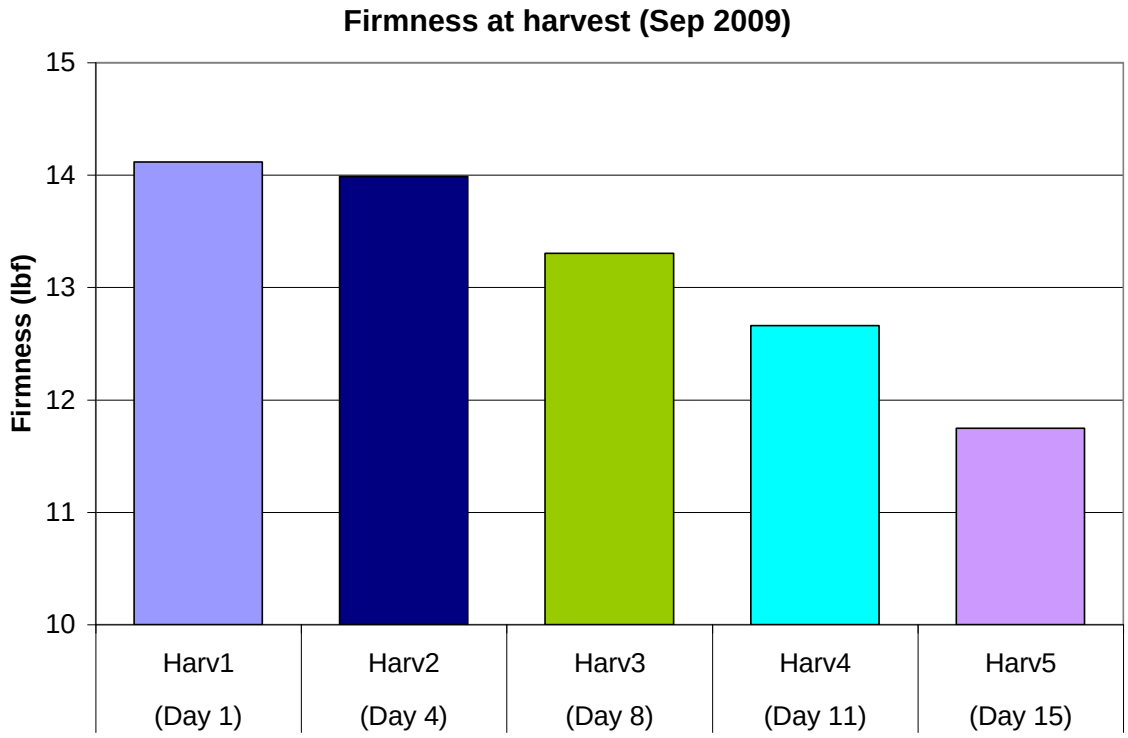


Figure 2. Firmness of pears on sequential harvest dates. Fruit was harvested from the same trees.

Fruit harvested on day 1 (14.1 lbf) ripened more slowly than fruit harvested later (Figure 3). Fruit harvested on day 1 did not soften to below 4 lbf even after 8 weeks in air storage. There was no difference in fruit harvested later. All needed 6 weeks of chilling before the firmness of ripened fruit fell to 4 lbf. None of the fruit approached 4 lbf prior to week 5, but after that time in storage fruit quality rose rapidly, especially the fruit harvested 7, 10 or 14 days after the initial harvest.

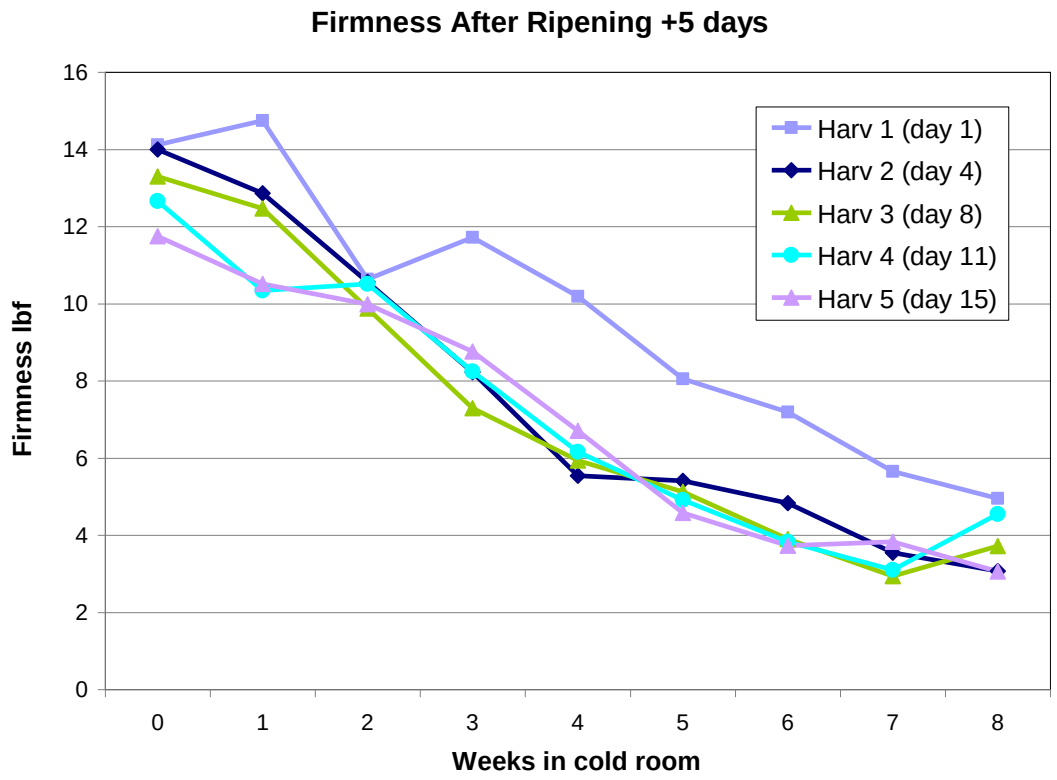


Figure 3. Firmness of fruit harvested from the same trees over time. Fruit was harvested, held at 33 ºF and samples were removed each week for 8 weeks and allowed to ripen.

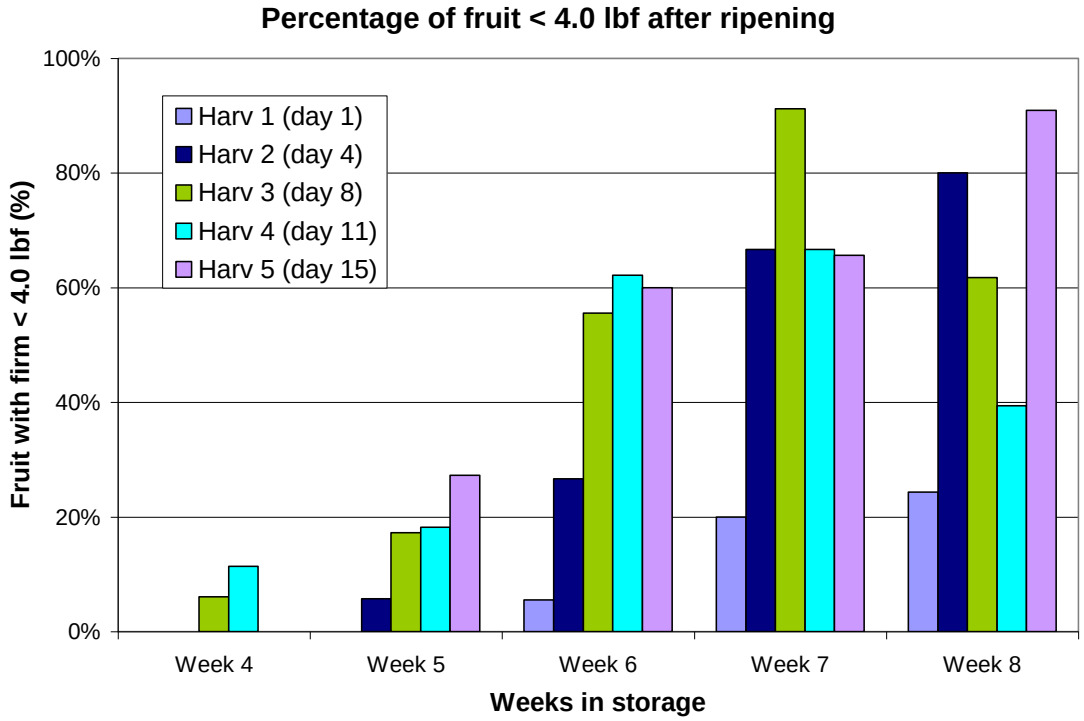


Figure 4. Firmness of fruit harvested over time after ripening expressed as the percentage of pears below 4 lbf.

Quality is more than firmness alone. Integrating firmness, sweetness, tartness, juiciness and flavor into an overall quality rating shows clearly that quality after ripening rises with length of time in cold storage (Figure 5).

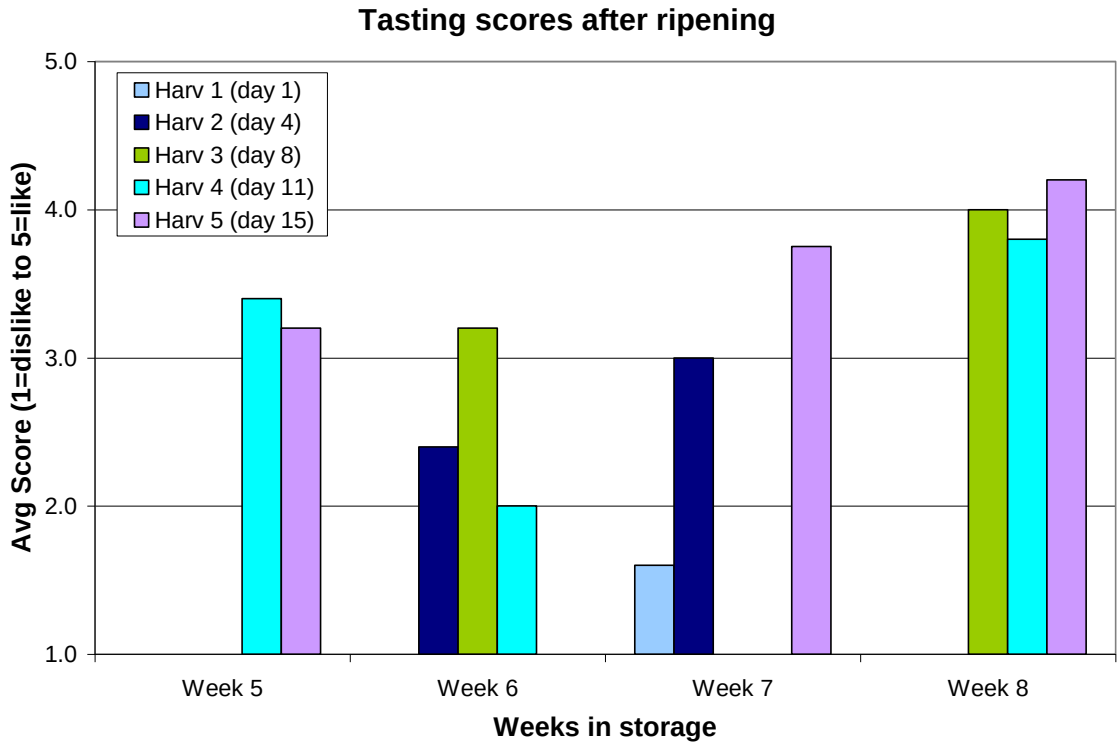


Figure 5. Tasting scores of pears harvested at multiple intervals after ripening (not all fruit was evaluated each week).

In conclusion, delaying harvest of Anjou pears reduced the postharvest chilling period and allowed both softening and quality attributes to develop earlier without conditioning.

When the chilling period was not met, what was the best conditioning treatment?

Pears from some orchards ripened with edible quality when conditioned (warmed to 65 ºF and treated with ethylene for 24 hours), while fruit from other orchards needed additional time exposed to ethylene. As the storage season progressed, there were more lots of fruit that ripened with quality after ethylene conditioning for 24 hours, or ripened without conditioning.

However, even when the chilling requirement had been met and fruit were capable of softening after cold storage, ethylene improved the uniformity of firmness and stimulate aroma volatile production. It took less ethylene to stimulate softening than to stimulate aroma production.

Fruit harvested early, as in fruit harvested for long-term storage but diverted to early season sales, took a longer time to be conditioned than those harvested later, in some cases as much as four days or more to condition with ethylene.

An additional factor in deciding on the length of conditioning is the firmness required to ship the fruit long distances. A current commercial requirement set by distribution centers is that fruit should be 8 lbf or greater to acceptable. In this case, the fruit needs to be at or above this firmness when shipped. Yet consumers demand fruit that softens within 4 days of purchase to 4 lbf or less. Conditioning technicians must be aware of this requirement.

Did pears respond uniformly to conditioning?

Anjou pear harvest is timed by both size and maturity of the fruit as measured chiefly by firmness. Fruit intended for long-term storage is harvested prior to that harvested for short-term storage or immediate sale. Orchards are also selected for long-term storage on the basis of historical performance. Superimposed on this program is that fact that fruit from certain orchards are not high enough quality to be stored for longer periods. Fruit from these orchards is often sold quickly after harvest. It is a commercial reality that both types of fruit (long-term quality and short-term quality) are selected to be conditioned in the fall for immediate sale. This initial variability increases the challenge of presenting to retailers pears of uniform ability to ripen.

Sixteen lots of Anjou pears from five different packinghouses in the Wenatchee River Valley were obtained between November 3 and 6, 2009. Upon receipt fruit firmness was tested and found to be quite variable (10.0 to 13.3 lbf) from lot to lot (Figure 6).

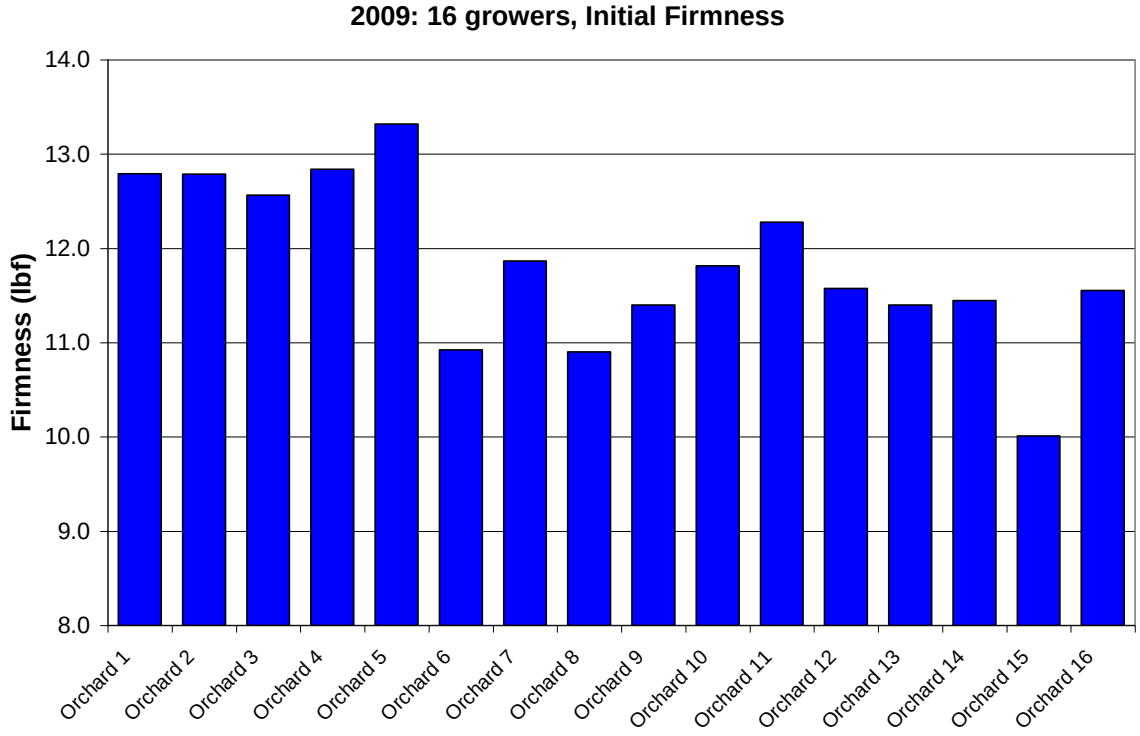


Figure 6. Average firmness of 16 lots of Anjou pears obtained from several packers in early November 2009.

Packers provided harvest dates for most of the lots (Table 7). The total chilling days (number of days after harvest) for each orchard prior to the start of conditioning ranged from 47 to 62 days (the harvest dates for Orchards 5 through 9 were not available).

Table 7. Chilling days for each orchard as estimated from harvest date of the fruit.

Orchard No.	Harv date	Chilling days
Orchard 1	12-Sep-09	58
Orchard 2	15-Sep-09	55
Orchard 3	19-Sep-09	51
Orchard 4	12-Sep-09	58
Orchard 5	NA	.
Orchard 6	NA	.
Orchard 7	NA	.
Orchard 8	NA	.
Orchard 9	NA	.
Orchard 10	17-Sep-09	53
Orchard 11	17-Sep-09	53
Orchard 12	8-Sep-09	62
Orchard 13	23-Sep-09	47
Orchard 14	22-Sep-09	48
Orchard 15	12-Sep-09	58
Orchard 16	23-Sep-09	47

Fruit these 16 orchards was subjected to one of three conditioning regimes and a control (no conditioning) treatment, after which the pears were held in the cold (34 ºF for 7 days) to simulate transport, then at 67 ºF for 5 days to ripen. Conditioning treatments included; 1 or 2 days of ethylene (65 ºF pulp and treatment temperature); and 2 days warm air (67 ºF pulp and treatment temperature). The control was simply held in the cold and then ripened at the same time as the conditioned fruit.

Firmness and skin color measurements were taken prior to conditioning, immediately after conditioning, immediately after simulated transport and again after ripening. Firmness immediately prior to conditioning ranged from 13.3 to 10.0 lbf. Firmness immediately after conditioning ranged from 6.1 to 13.8 lbf (Figure 7). The extent of firmness loss was relative to initial firmness and treatment type. Softer fruit lost loss more firmness than harder fruit. Fruit conditioned for a longer time (2 days) lost more firmness than fruit conditioned for a shorter time (1 day) (Table 8).

The change in skin color was essentially the same for all conditioning treatments, going from an average of 4.1 initially to an average of 4.4 after transport (1 = dark green to 10 = yellow scale). After ripening, the skin color averaged 6.1 for the 1-day ethylene and 2-day warming treatments and 6.8 for the 2-day ethylene treatment.

Fruit that were not conditioned held their firmness and green color during the time they were held in storage and simulated transport (total of 9 days). Thus this fruit would have arrived at the distribution center at the same firmness it started with, with a skin color of 4.8 (1 to 10 scale).

Table 8. Loss in firmness from time of receipt to immediately after conditioning (max and average) and average firmness after ripening for each treatment.

Treatment	Firmness loss after conditioning		Firmness after Ripening	
	Max (lbf)	Avg. (lbf)	Avg. (lbf)	Stdev
1-day ethylene	1.6	0.4	2.1	*1.4*
2 days ethylene	4.7	2.1	1.7	*0.7*
2 days warm air	5.8	3.0	2.8	*2.1*
No conditioning	NA	NA	4.1	*2.3*

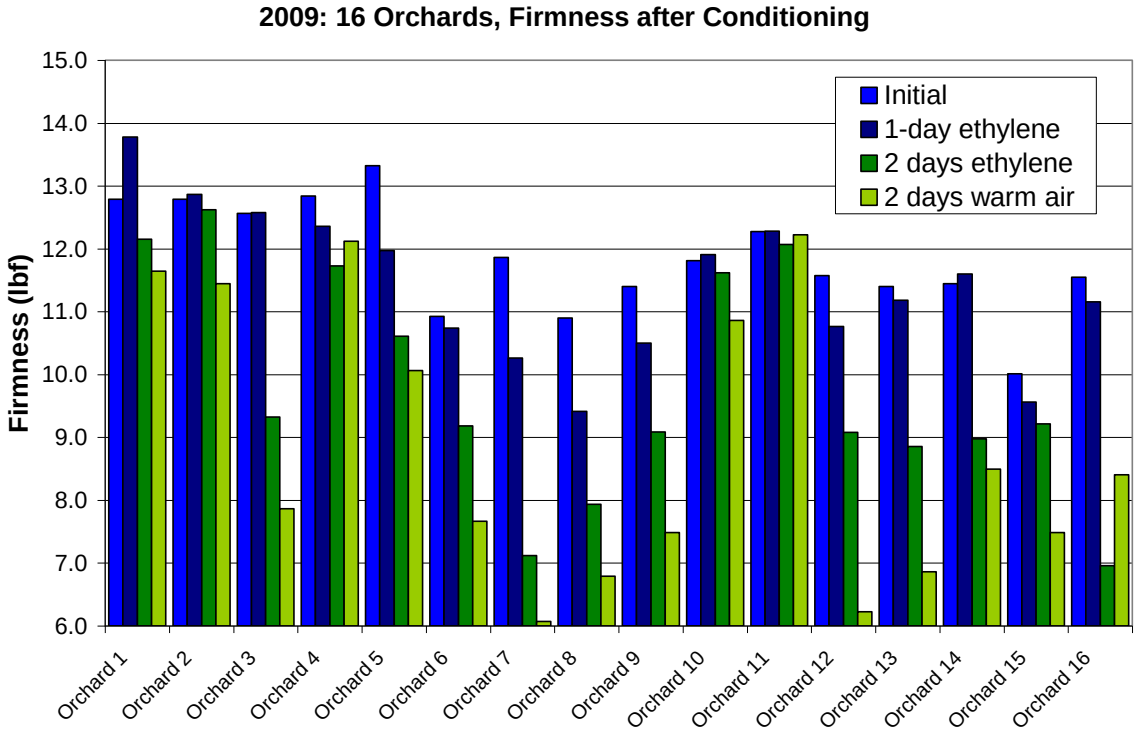


Figure 7. Firmness of each lot of pears prior to conditioning (initial) and immediately after conditioning (1 or 2 days ethylene or 2 days warm air).

Following conditioning fruit were placed in a cold storage room (34 ºF) and held for an additional 7 days to represent transit. During this simulated shipment softer fruit continued to lose firmness.

Following simulated transit, fruit were allowed to ripen for 5 days at 68 ºF (Figure 8). A number of lots of the fruit that had not been conditioned did not soften, and in all cases the non-conditioned fruit was firmer than the conditioned fruit. After ripening fruit that had been conditioned for two days were softer than those conditioned for one day.

Fruit conditioned with ethylene had a lower range in firmness after ripening than fruit conditioned without ethylene. All the fruit treated for two days with ethylene after ripening ranged between 1.2 and 2.7 lbf – ideal eating firmness. Those treated with ethylene for one day ranged between 1.2 and 4.1 lbf. Fruit conditioned without ethylene did not ripen uniformly and

ranged between 1.3 and 5.5 lbf. This indicates that ethylene conditioning harmonizes ripening. Fruit was not conditioned ranged between 2.6 and 6.4 lbf, which would leave the retailer or consumer with a high degree of variability in final firmness.

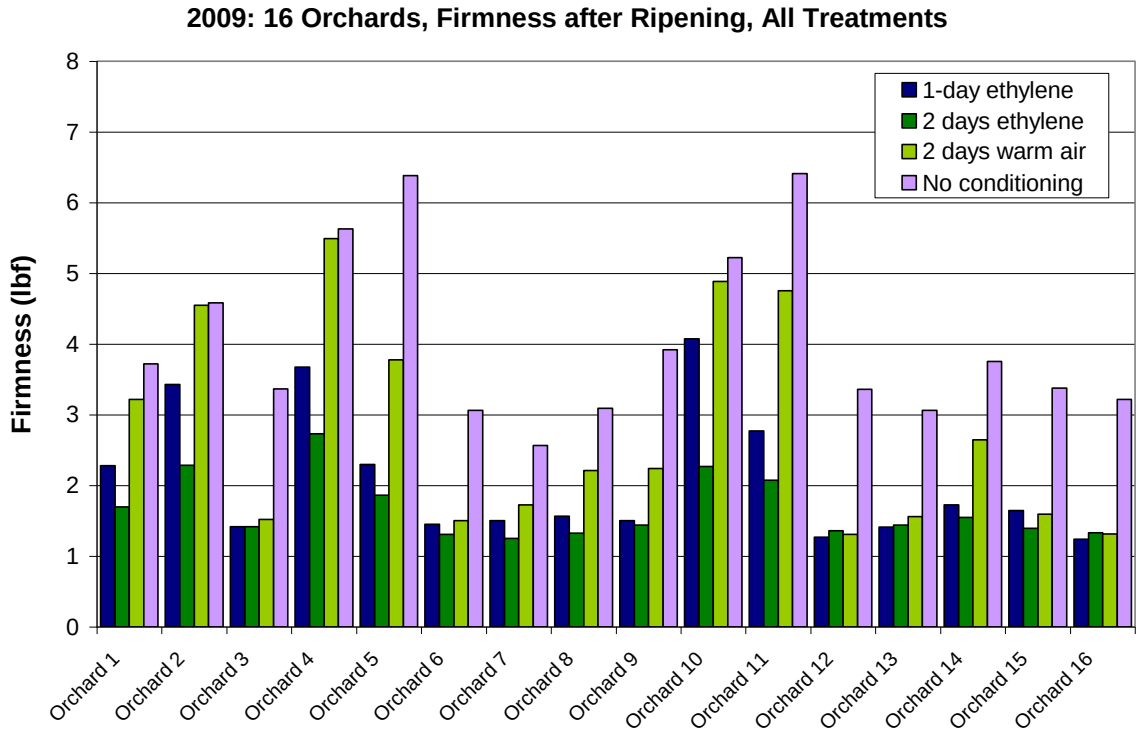


Figure 8. Average firmness by orchard and treatment for fruit after ripening for 5 days.

Will conditioned fruit be acceptable at distribution centers?
Industry sources have said that the minimum firmness is set at 8 lbf after transport to be acceptable by distribution centers. In our experiment with 16 orchards, fruit that had not been conditioned were above 8 lbf after shipment (Figures 9a, b, c and d). One day in ethylene resulted in 50% of the lots being above 8 lbf. Two days in ethylene resulted in 31% of the lots above 8 lbf. Fruit warmed for two days without ethylene resulted in 37.5% of the lots above 8 lbf.

The firmness after ripening was highly variable in the fruit that had not been conditioned and less variable in fruit that had been conditioned with ethylene.

A major question remains as why some fruit lost significant amounts of firmness while other lots remained firm. Generally it appears that those lots which have higher firmness levels lose less firmness than those with lower starting firmness. Based on firmness the 16 lots of fruit can be separated into two groups – those of high firmness remained high through out any of the conditioning treatments while those of lower firmness remained low.

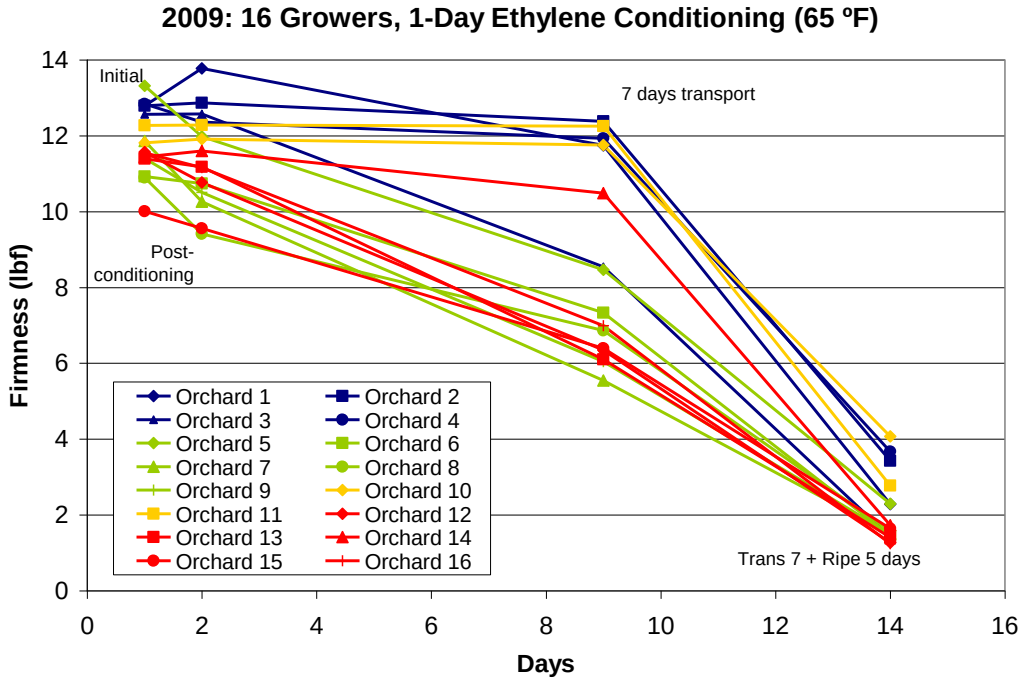


Figure 9a. Firmness of fruit prior to conditioning, immediately after conditioning, immediately after simulated transit and ripening. Fruit was warmed for 24 hours, treated with ethylene for 24 hours and cooled (Nov. 2009).

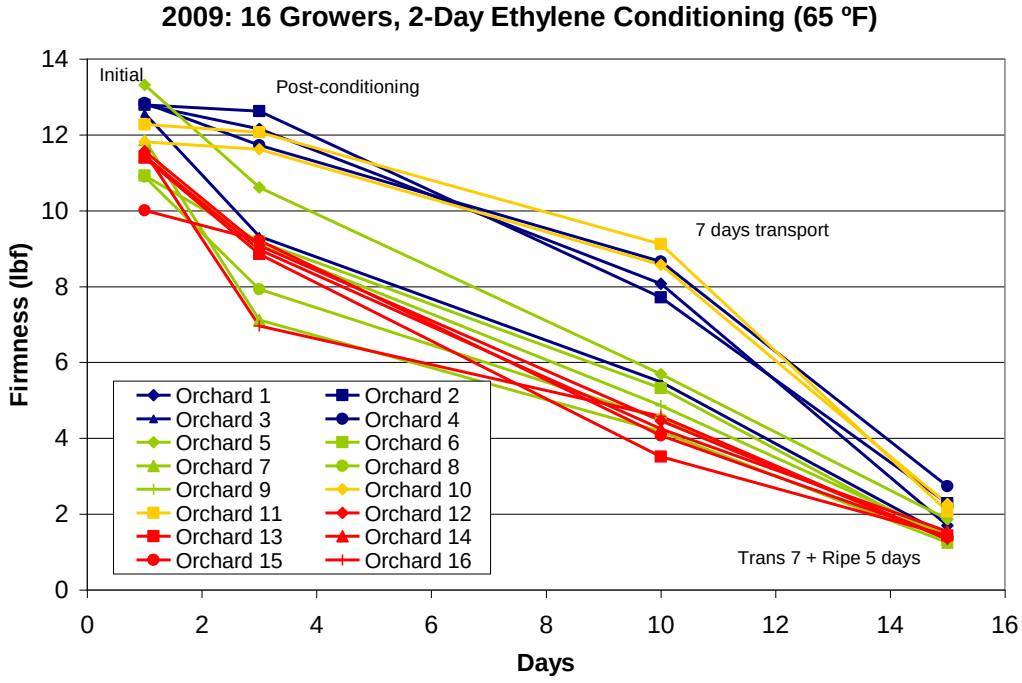


Figure 9b. Firmness of fruit prior to conditioning, immediately after conditioning, immediately after simulated transit and ripening. Fruit was warmed for 24 hours, treated with ethylene for 48 hours and cooled (Nov. 2009).

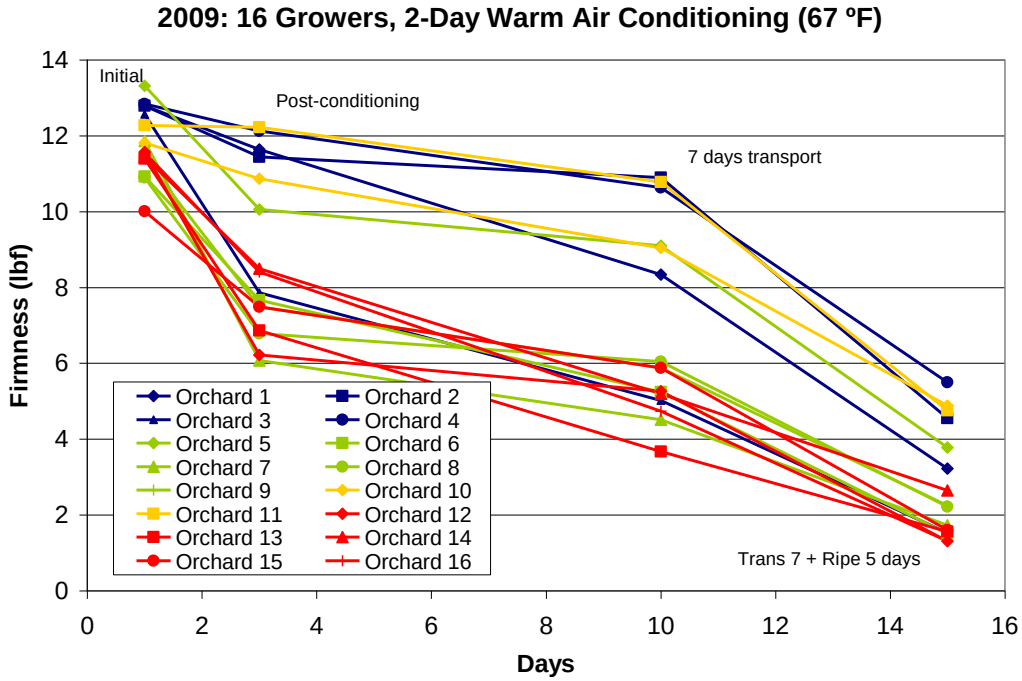


Figure 9c. Firmness of fruit prior to conditioning, immediately after conditioning, immediately after simulated transit and ripening. Fruit was warmed for 24 hours, warmed without ethylene for 48 hours then cooled (Nov. 2009).

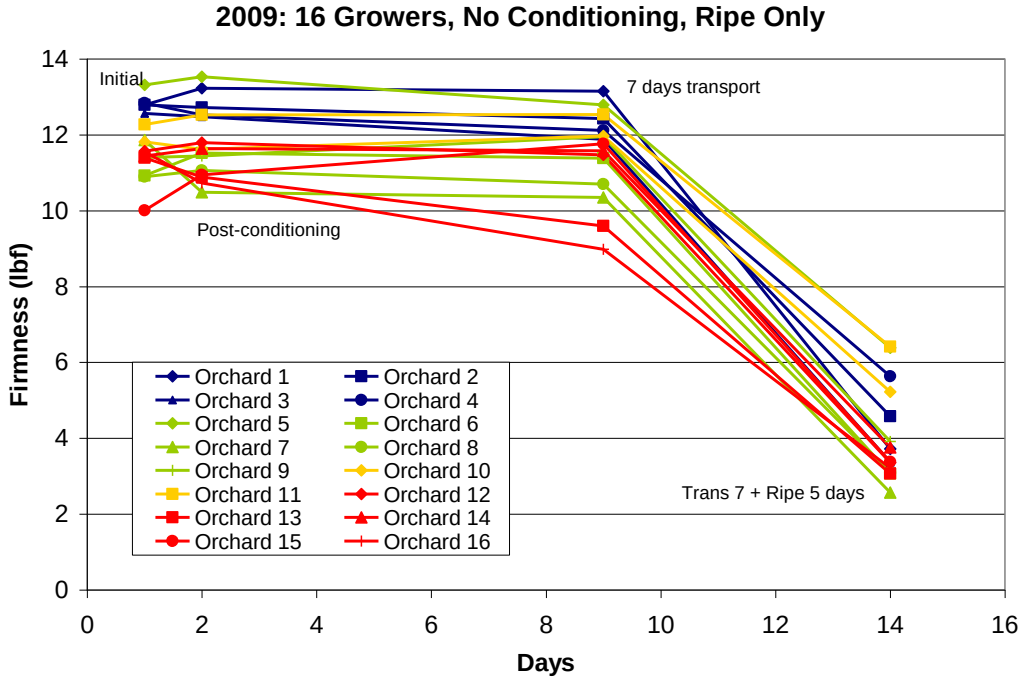


Figure 9d. Firmness of fruit prior to conditioning, immediately after conditioning, immediately after simulated transit and ripening. Fruit was held in cold storage; no conditioning treatment applied (Nov. 2009).

What was the effect of fruit and treatment temperature during conditioning on speed of ripening?

Several experiments were conducted to determine the effect of fruit and ambient conditioning temperatures on the rate of softening. In the first experiment fruit from one grower was conditioned with the fruit temperature at 60, 65 or 70 ºF and the air temperature during conditioning was either 65 of 70 ºF (Figure 10). Fruit firmness was affected only slightly immediately after conditioning and transport, but there was no difference in fruit firmness after ripening.

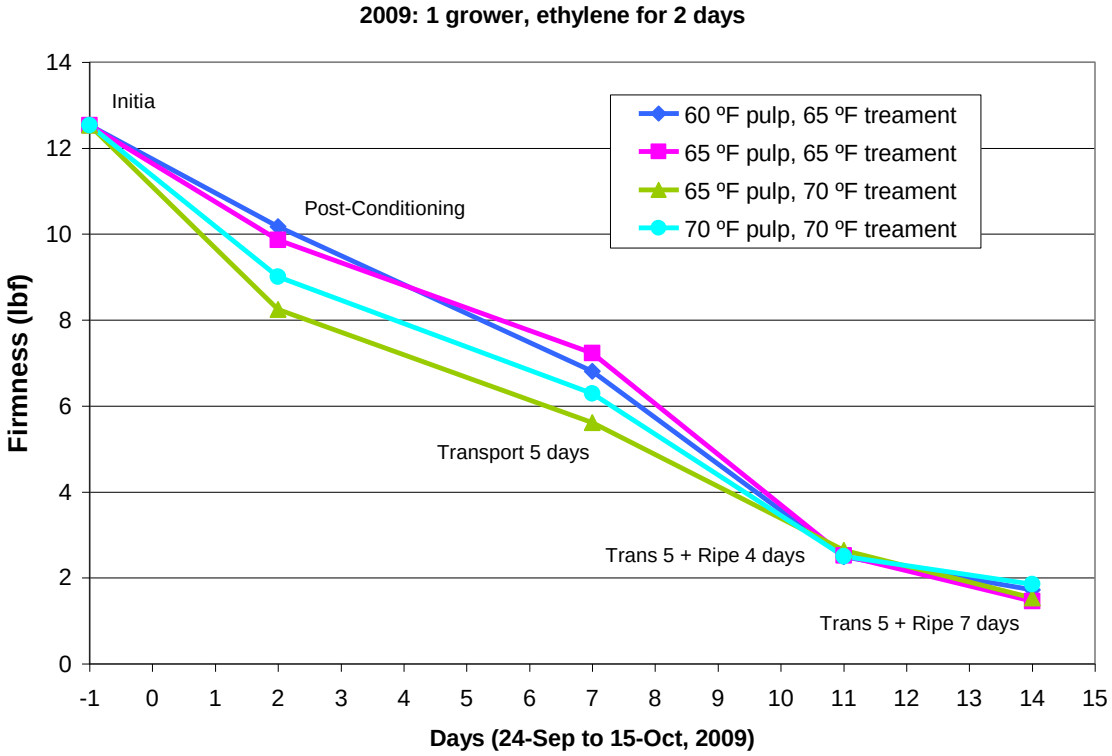


Figure 10. Average firmness of one grower lot of fruit conditioned for 2 days with ethylene at different pulp and air temperatures.

In a second experiment, fruit softening after conditioning and ripening were compared using two temperatures and two different grower lots. The warmer treatment (70 ºF) of the Grower A fruit resulted in fruit that was softer after conditioning or transit, but harder after ripening (Figure 11a). The warmer treatment (70 ºF) of the Grower B fruit resulted in no difference after conditioning or transit, and slightly softer fruit after ripening (Figure 11b).

Once again the difference in fruit behavior from different grower lots can amplify or suppress a treatment effect.

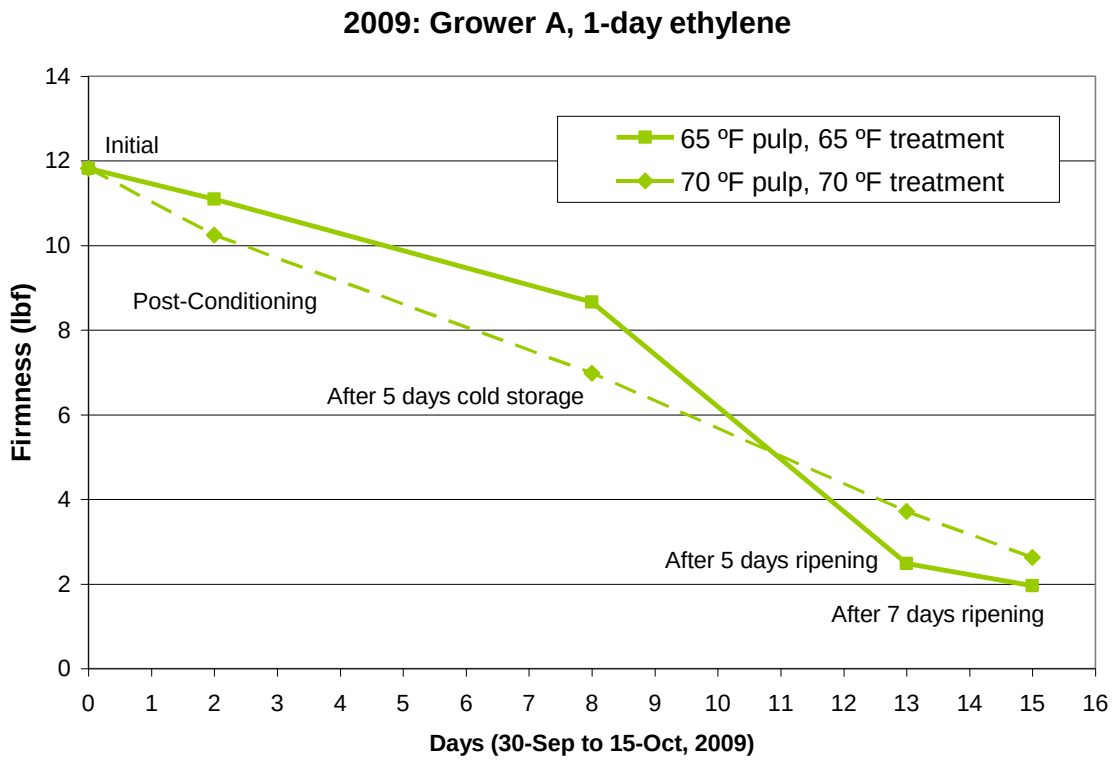


Figure 11a. Firmness of one grower lot (Grower A) conditioned at either 65 ºF pulp and air temperature or 70 ºF pulp and air temperature.

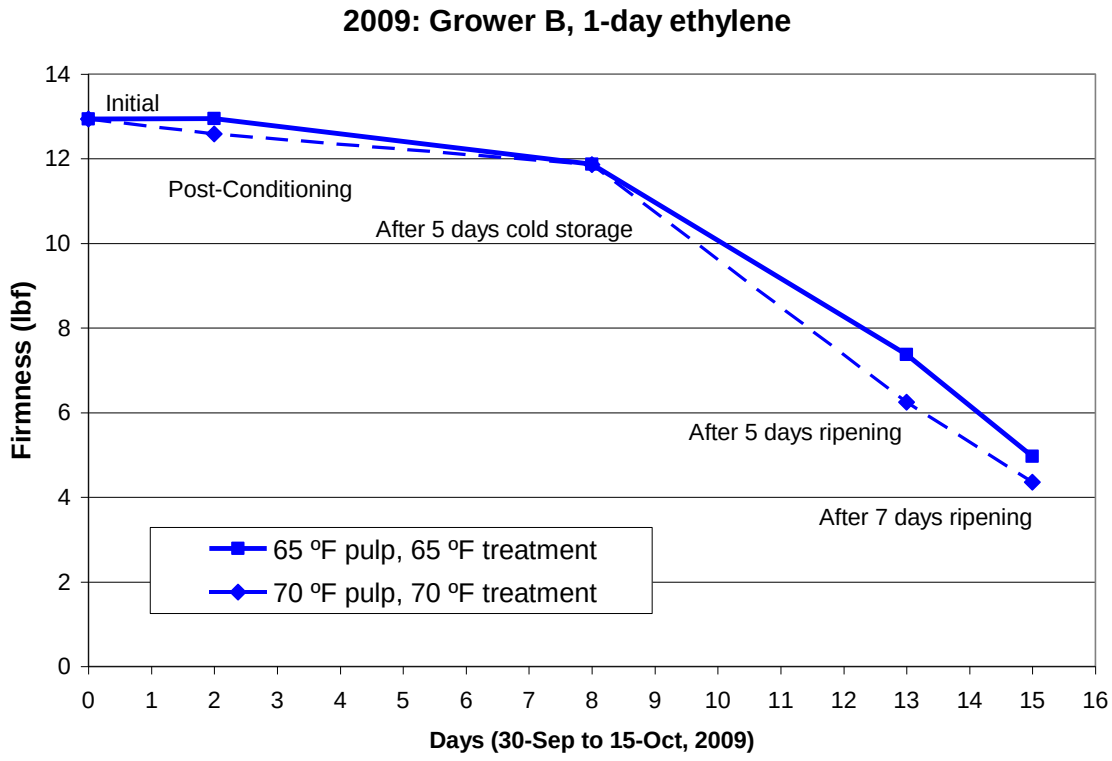
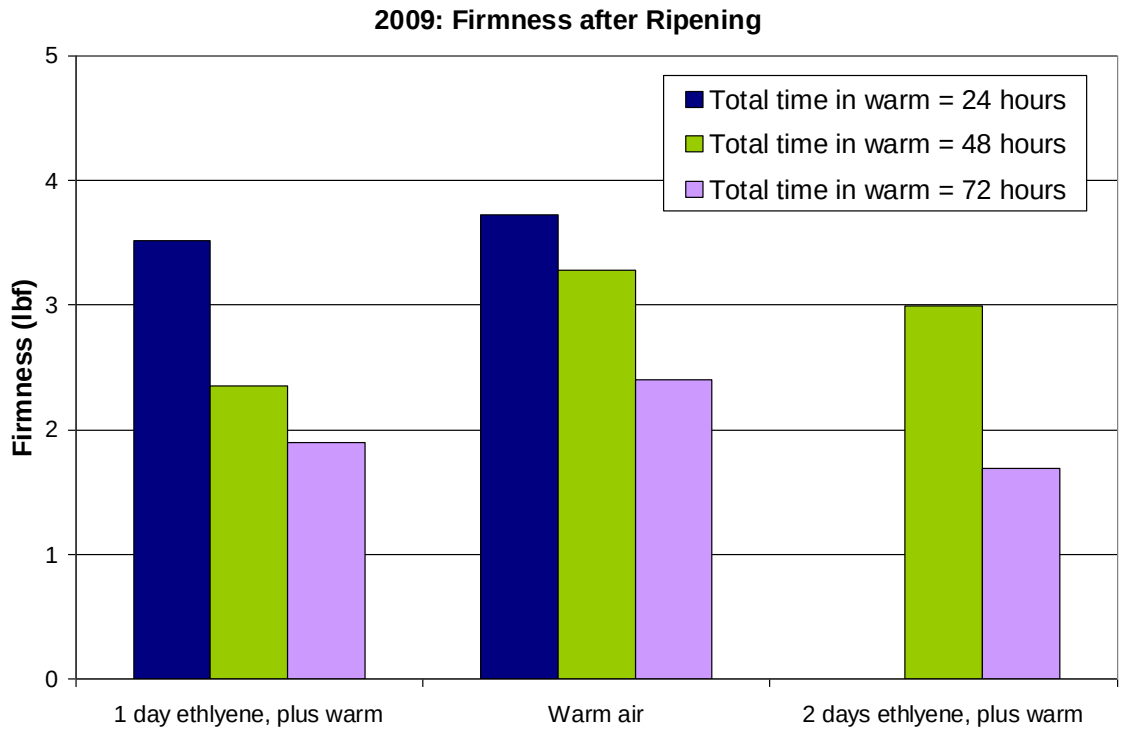


Figure 11b. Firmness of one grower lot (Grower B) conditioned at either 65 ºF pulp and air temperature or 70 ºF pulp and air temperature.

What was the effect of post-conditioning temperature on ripening?

The effect of holding the fruit in the warm as part of conditioning or after conditioning was to hasten softening (Figure 12). Fruit softened rapidly when the conditioning temperature was prolonged. This speaks to the need to maintain a rigid schedule of warming and re-cooling if predictability is desired.



* All fruit was held at room temperature for 24 hours prior to the start of conditioning.

Figure 12. Loss in fruit firmness as a result of hours in warm, either as part of the conditioning regime or by holding fruit at warm temperatures. This experiment was done on one lot of fruit.

How much firmness was lost during conditioning and shipping?

Examination of the effect of 1 day of ethylene conditioning on 16 grower lots of pears reveals how difficult it is to predict how much firmness will be lost during conditioning and transport (Figures 13a, b and c). Fruit from 6 orchards did not lose any firmness during conditioning, while fruit from 3 orchards lost over 1 lbf (Figures 13a and b). Similarly, fruit from 4 orchards lost less than 1 lbf during transport while fruit from 6 orchards lost more than 4 lbf (Figure 13c).

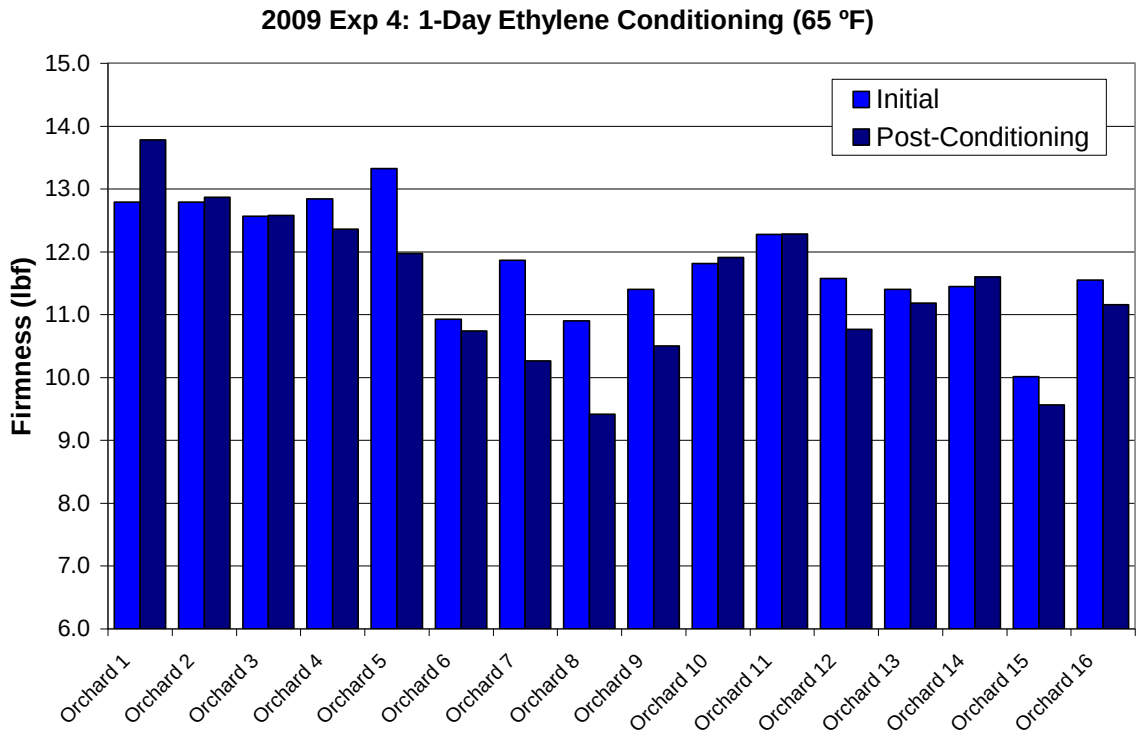


Figure 13a. Comparison of initial firmness with firmness immediately after conditioning.

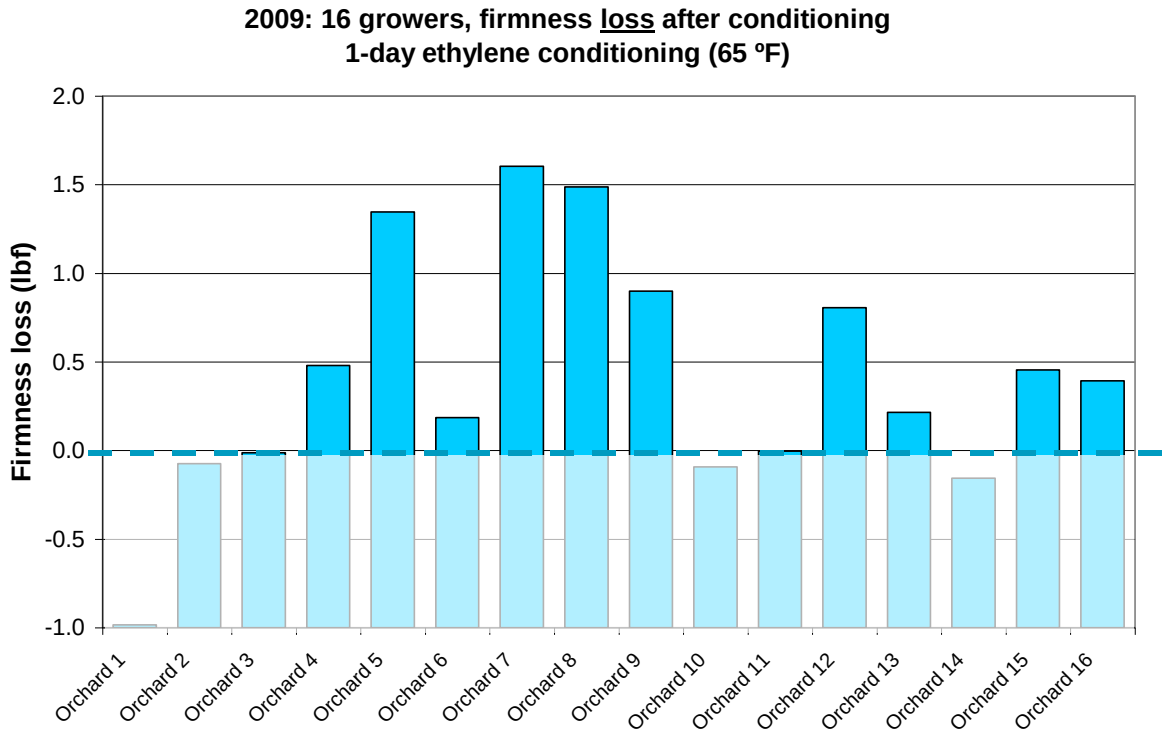


Figure 13b. Initial firmness minus firmness after 1-day conditioning, illustrating the amount of firmness lost during conditioning.

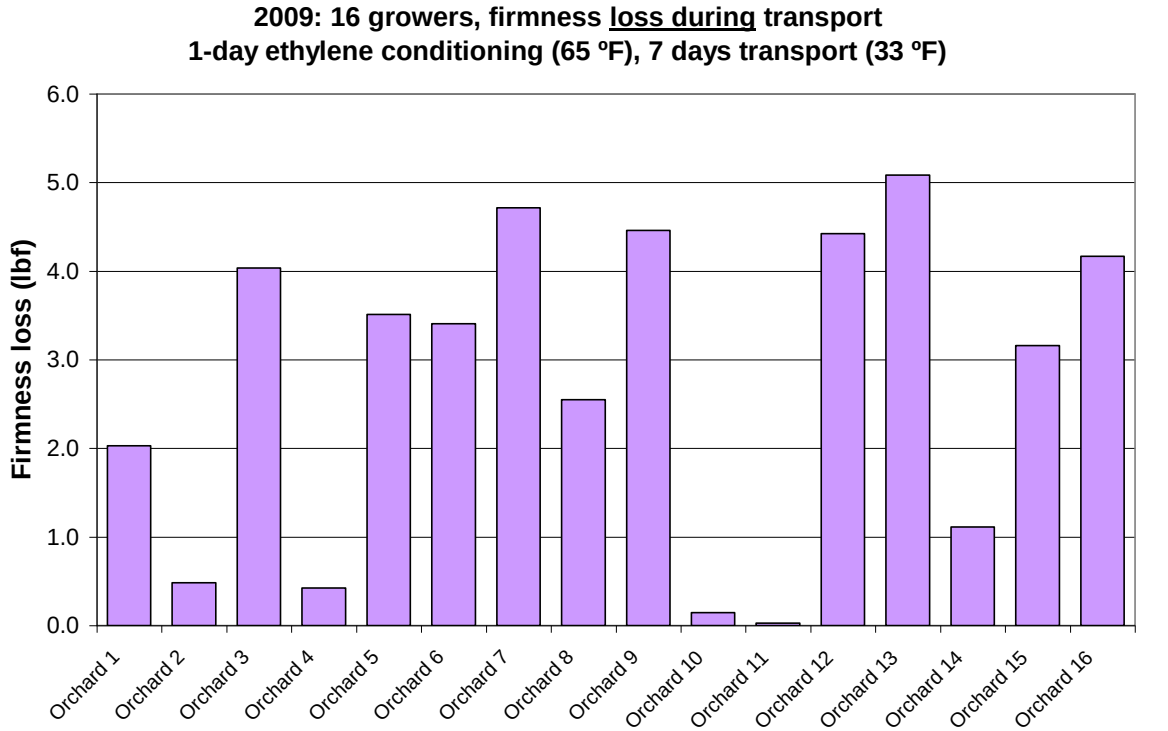


Figure 13c. Firmness after 1-day conditioning minus firmness after 7-day transport illustrating the amount of firmness lost during simulated transport, when fruit were held at 33 ºF for 7 days.

Did the concentration of ethylene influence the speed of ripening after conditioning?

Fruit from two growers were treated with either 20 ppm or above 200 ppm ethylene for 24 hours at 65 ºF. There was no significant effect of ethylene concentration on the firmness of the fruit after ripening.

What were the differences in response in fruit packed in polylined hand-wrapped boxes vs. Euro Boxes?

There was no difference in ethylene levels within standard hand-wrapped boxes with polyliners or unwrapped Euro tray boxes (Figure 14a). There was a difference in oxygen and carbon dioxide levels. Oxygen was slightly lower and carbon dioxide was significantly higher in the boxes than in the Euro containers (Figures 14b and 14c). There was no sign of fruit damage at this carbon dioxide level. There was also a difference in the fruit temperatures between the Euro and standard boxes. The standard hand wrapped pears warmed 5 to 6 hours slower than pears in the Euro trays (Figure 14d).

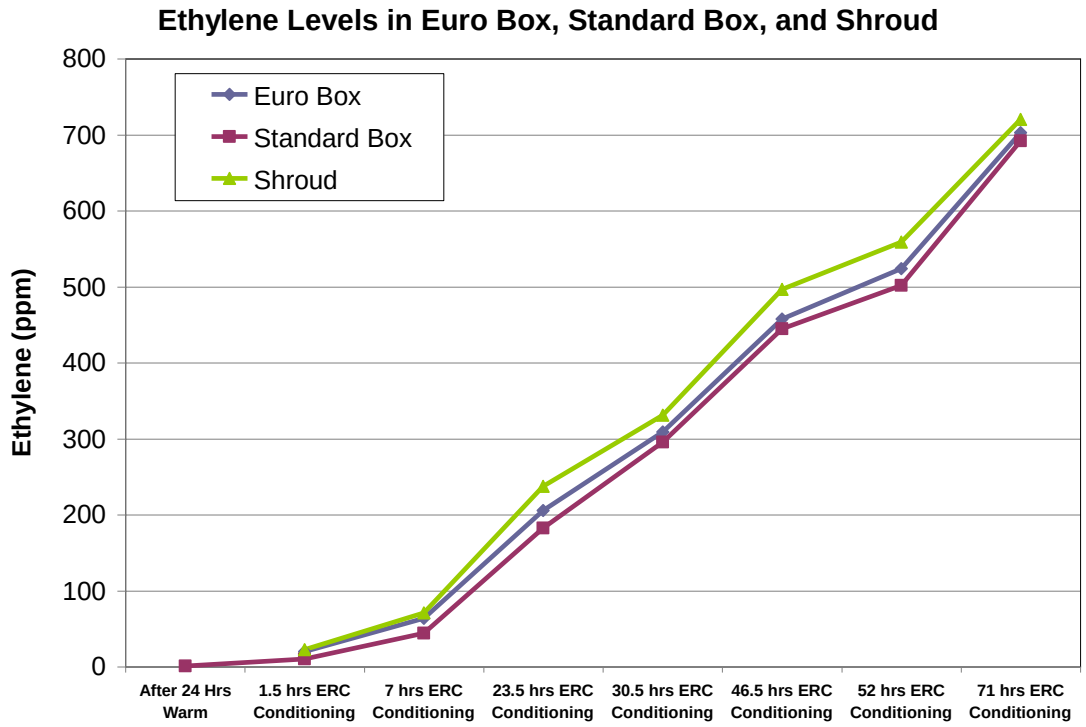


Figure 14a. Levels of ethylene inside standard polylined boxes, Euro tray boxes and within a shroud as applied by an Ethylene Release Canister (ERC).

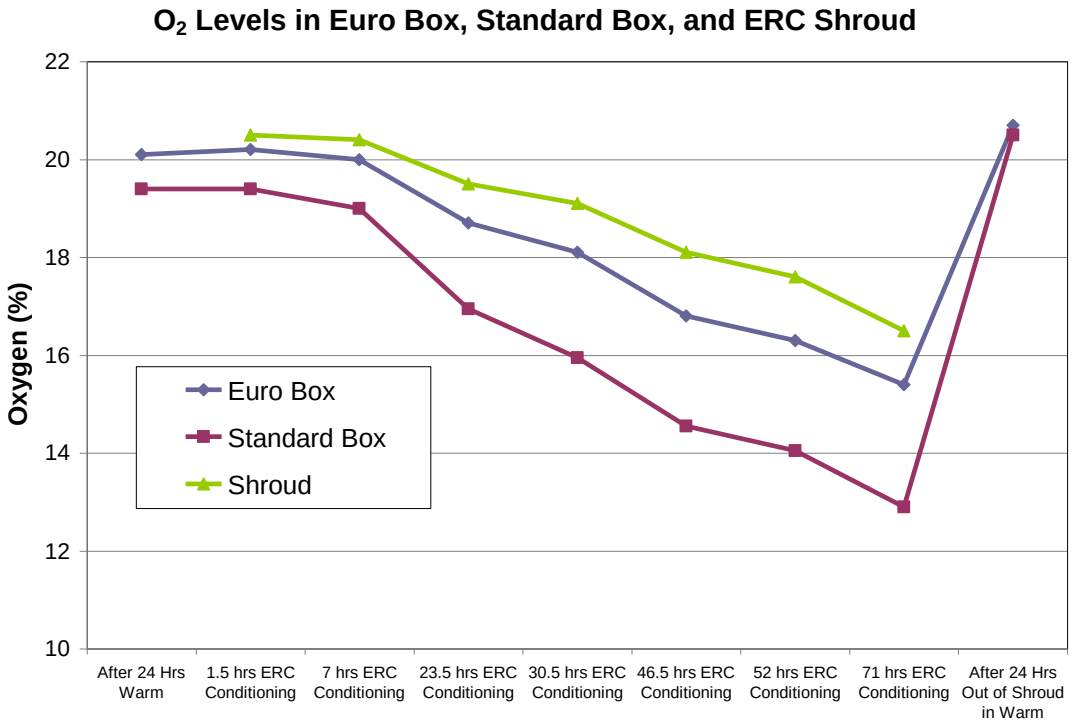


Figure 14b. Levels of oxygen inside standard polylined boxes, Euro tray boxes and within a shroud during ethylene application using an Ethylene Release Canister (ERC).

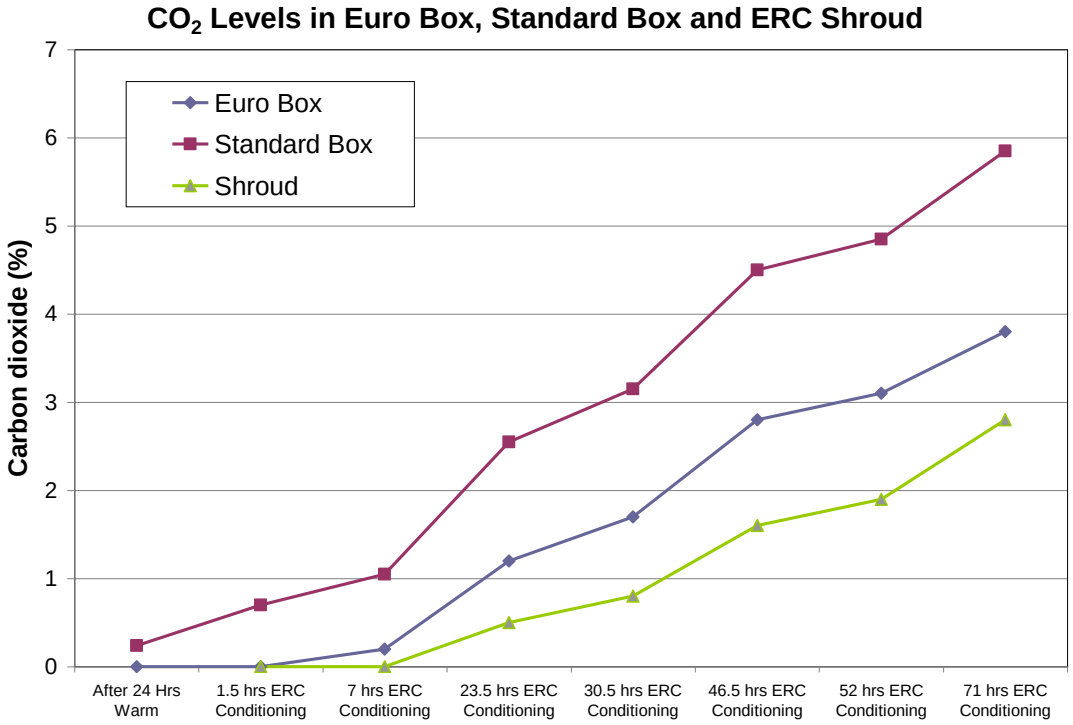


Figure 14c. Levels of carbon dioxide inside standard polylined boxes, Euro tray boxes and within a shroud during ethylene application using an Ethylene Release Canister (ERC).

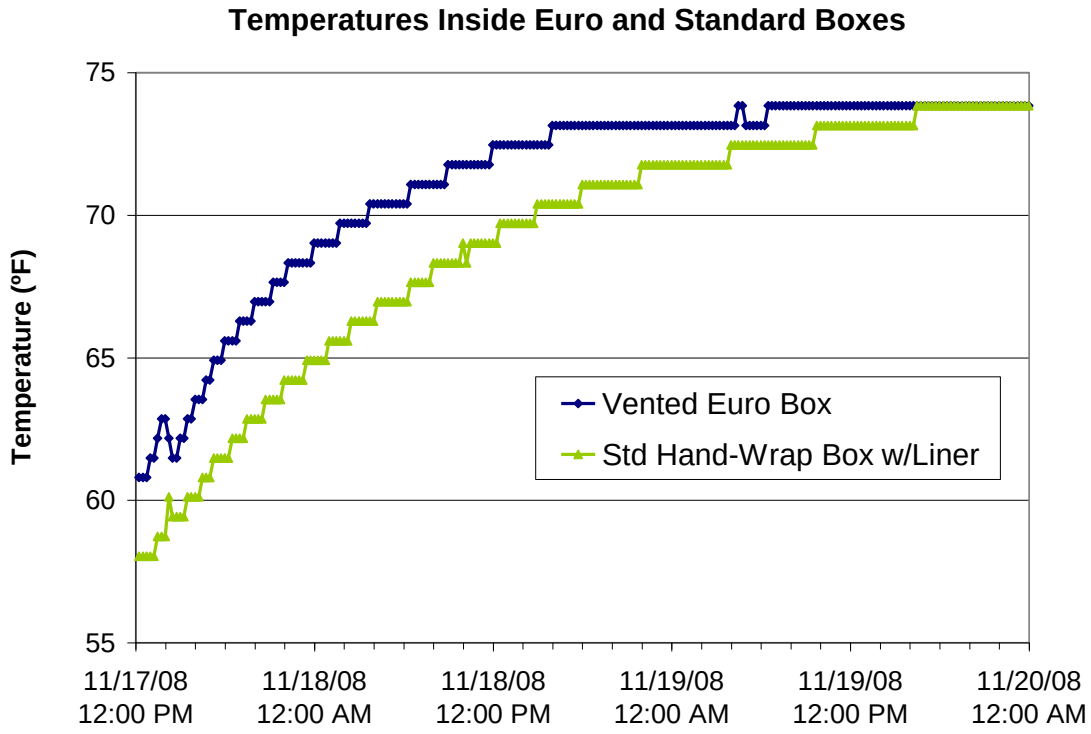


Figure 14d. Fruit temperature in standard polylined boxes vs Euro tray boxes.

Did soluble solids or acidity change during conditioning and ripening?

Measurement of soluble solids and acidity change prior to and after conditioning did not show significant or predictable changes in either compound.

What was the relationship of price and quality in local markets?

There was little correlation between price and ability of the pears to ripen among pears purchased in Wenatchee in October 2009 (Figure 15). None of the pears were labeled as having been conditioned.

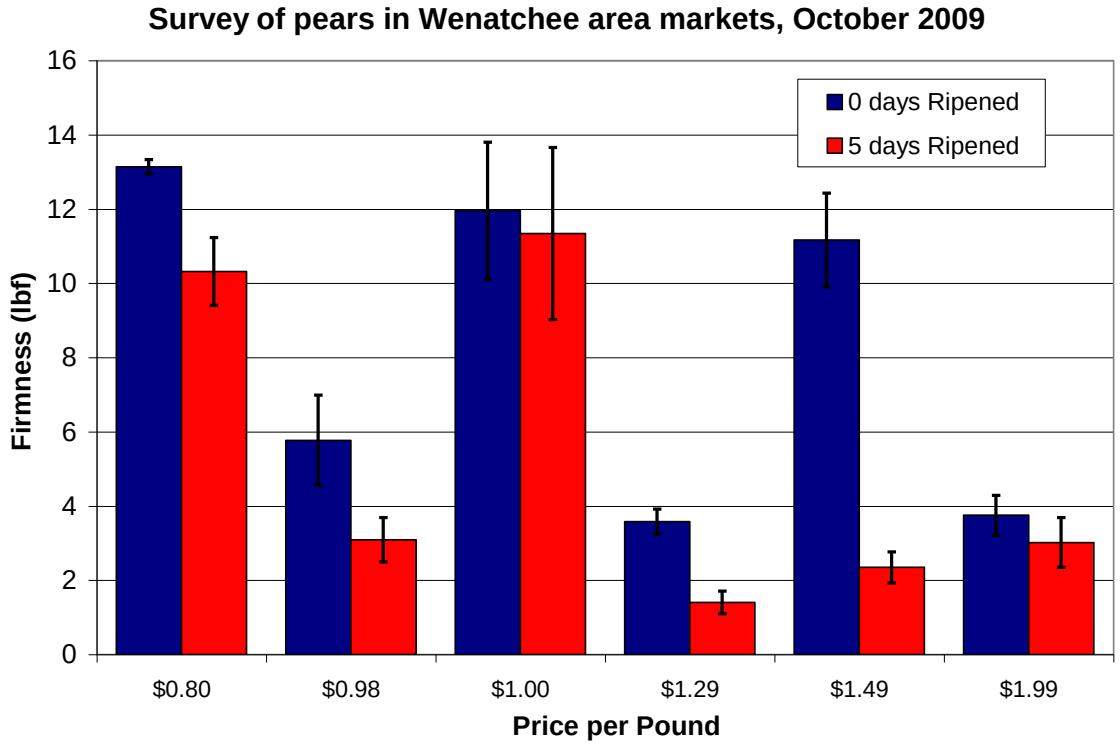


Figure 15. Relationship between the initial firmness, firmness after ripening and retail cost (pears purchased in six different Wenatchee markets, October 2009).

What was the effect of commercially applied SmartFresh on Anjou pear conditioning and ripening?

A cooperating packinghouse allowed us to condition and ripen pears that had been treated with 100 ppb SmartFresh after harvest. This fruit was stored in bins in commercial CA until April 2009 and then packed. Fruit came out of CA at 13 lbf. It was warmed then conditioned as listed in Table 9. Note: The pears conditioned at 73 ºF developed bright green spots and uneven background color between the pears, while those conditioned at cooler temperatures or not conditioned had more uniform color and did not develop spots.

Anjou pears treated with 100 ppb did ripen to an acceptable firmness within 5 days. Conditioning this fruit with ethylene allowed the fruit to ripen faster (Figure 16).

Table 9. Conditioning treatments for Anjou pears treated with SmartFresh at 100 ppb. Firmness after conditioning and ripening, SmartFresh-treated Anjou pears, April 2009.

	Firmness (lbf)				
			Ripe		
No.	Initial	Post-conditioning	4 Days	7 Days	Conditioning Treatment
1	12.9	13.1	4.4	1.7	24 hr warm (62 ºF) + 24 hr ETH
2	13.1	10.7	3.1	1.4	48 hr warm (62 ºF) + 24 hr ETH + 24 hr warm (73 ºF)
3	12.7	6.8	2.5	1.9	48 hr warm (73 ºF) + 24 hr ETH + 24 hr warm (73 ºF)
4	13.2	10.6	2.7	1.9	24 hr warm (62 ºF) + 48 hr ETH
5	13.0	7.2	2.3	1.7	24 hr warm (73 ºF) + 48 hr ETH + 24 hr warm (73 ºF)
6	12.9		4.0*	3.1	No conditioning, ripening only (73 ºF)

* Treatment 6 (no conditioning was ripened for 5 and 7 days. All fruit was ripened at 73 ºF.