CONTINUING PROGRESS REPORT **YEAR 3/3**
(Note: this project will conclude in spring 2006)

Project title:	Ethylene ripening of pears by unconventional means
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OVERALL PROJECT GOAL

This project aims to test the potential of unconventional approaches to ethylene conditioning to expand the market window for winter pears, particularly 'Green Anjou'. This has involved firstly confirming the reported need over the first month of storage for more prolonged and elevated exposures to ethylene than are practical using conventional conditioning methods. That knowledge has then been applied in testing the usefulness of our prototype Ethylene Release capsules (ERCs) as a viable alternative means of achieving optimal conditioning without requiring expensive conditioning facilities.

OBJECTIVES FOR 2006:

- Continue to determine the influence of ethylene concentration and length of conditioning period at 68°F on subsequent softening and aroma production by 'Green Anjou' (in USA) and 'Comice' (in New Zealand) after one and 3 weeks of cold storage. (This includes work still to be carried out in March 2006, so reporting on this objective has been deferred until next year).
- Test the use of ERCs for pre-conditioning 'Green Anjou' in boxes immediately prior to and during transport to the East Coast. Conditioned fruit to be compared in terms of eating quality and cosmetic attributes with fruit given the current industry standard conditioning, after all have been further ripened to a similar extent upon arrival.

Significant findings

- Ethylene permeated rapidly and uniformly within standard cartons and Euro-packs of 'Green Anjou' pears containing ERCs within the standard polyliner. ERCs maintained minimum ethylene levels of 65 ppm for at least 7 days in these packages.
- Conditioning of early season 'Green Anjou' using ERCs inside conventional cartons and Euro-packs for one day at ambient temperature, followed by gradual cooling before and during trucking, resulted in a greater ripening potential and more flavorsome fruit than did standard one day forced air ethylene conditioning of pre-warmed fruit in a trailer or three days of warming without ethylene.
- In-transit conditioning occurred in all the ERC-conditioned packages as they were inadequately chilled after conditioning and retained the ERCs that continued to release ethylene during transport.
- Euro-packs were better than cartons or clamshells for delivering ERC-conditioned fruit to the market place. Less than 1% of the fruit were found to be bruised in Euro-packs, even amongst treatments that had softened to just 3 lb by the end of trucking across the USA.

- Some in-transit bruising damage (<5%) occurred in fruit ERC-conditioned in standard cartons that arrived almost ready-to-eat (2.2-5.2 lb mean firmness), but firmer fruit (7.6 lb mean on arrival) were undamaged and ripened to 2.9 lb mean firmness in five days at ambient temperature.
- Consumers were unable to detect a difference between fruit ERC-conditioned in cartons for 1, 3 or 5 days but preferred them to those that had been simply warmed in cartons for three days.
- A half-pallet of cold 'Green Anjou' at two weeks after harvest, conventionally wrapped and packed in standard cartons and Euro-packs and sealed under a disposable pallet cover, was conditioned effectively and reasonably uniformly with ERCs in 5 days at ambient temperature.

Methods

ERC-conditioning of fruit in cartons and Euro-packs sealed in a standard plastic pallet cover

The prototype ethylene release capsule (ERC) consisted of a small plastic cylinder (20 mm diam. x 35 mm long) that released ethylene at a controlled rate for at least seven days. 'Green Anjou' pears were taken from cold storage after 13 days and conventionally packed into standard cartons and in double-layer vented Euro-packs within standard polyliners. These were used to compile a stack comprising 14 cartons in the two lower tiers and 15 Euro-packs in the three upper tiers, all placed on plastic film covering a slip-sheet on a pallet. Thirty ERCs in two strips three feet apart were then placed on top of the Euro-packs and the load sealed within a standard disposable 80 µm polythene pallet cover. The boxed fruit were then allowed to warm up and condition at about 68°F for five days. Control fruit from the same batch were similarly packaged and sealed but received no artificial ethylene.

A radio-temperature sensor probe was inserted through the plastic cover into a central space between boxes to record internal and external temperatures every 12 hours. The internal air temperature at the start was 50.4ºF. Three narrow Teflon tubes were inserted into a bottom-tier carton, a third-tier Euro pack and a central air gap for daily sampling to measure ethylene, CO_2 and O_2 concentrations.

When the plastic cover was removed, mean fruit firmness was assessed daily on 60 fruit from each of three treated Euro-packs and cartons taken from various locations in the stack. Every second day, 10 fruit were also sampled from each of the four control treatments for firmness testing.

ERC-conditioning of fruit in single clamshells, Euro-packs and standard cartons

'Green Anjou' pears used in this work were picked near Peshastin WA on 14 September 2005, graded into cherry bins and placed in 30^0F cold storage. Cold fruit (90 count) were then packed into 80 count 4-pack clamshells, double-layer vented Euro-packs and cartons on 21, 23 and 25 September. An ERC was placed in the central well of each clamshell. Each Euro-pack containing 47 fruit had 4 ERCs added to the empty pocket in the top layer of fruit. Each carton containing 80 hand-wrapped fruit had 5 ERCs placed in a cavity in the top layer. To minimize ethylene loss, the standard poly-liner in each box type was neatly folded over the top layer of fruit. There were five replicates of each box type and 50 clamshells per treatment.

Fruit from the same batch as above were also conditioned in Euro-packs and cartons using a commercial trailer and typical protocol (warmed for about 12 hours, followed by 1 day in 1000 ppm ethylene at 68ºF). In addition, fruit in all three types of packaging were simply warmed at room temperature for three days without artificial ethylene from ERCs.

For ERC-conditioning, the packages were kept separate on roller racks in a large well-ventilated packhouse in Wenatchee WA that held a stable temperature of 68ºF. To monitor temperatures every thirty minutes during conditioning, storage and shipping, nine i-Button® temperature loggers were placed amongst the fruit inside representative boxes or clamshells. After conditioning for 1, 3 or 5

days, the packages were transferred to a holding cold-storage room at 42-52ºF (47.3ºF mean). Fruit firmness and ethylene levels inside the polyliners were assessed at the end of the conditioning period.

Fruit ripening at Raleigh, North Carolina

The packaged fruit were palletized and transported in a refrigerated truck with a full load of 'Granny Smith' apples from Wenatchee WA to Raleigh NC in about 4.5 days. Upon arrival, the load was transferred to a large well-ventilated basement room in Schaub Hall (Southeast Dairy Foods Research Centre, North Carolina State University). The ethylene concentration in each package was then immediately assessed, the ERCs removed and the fruit within the packages allowed to ripen normally at 68°F for a maximum of five days. This was considered to be a reasonable period in which to expect fruit to reach ready-to-eat condition after delivery. During the ripening period, fruit from various conditioning treatments were sampled regularly to assess firmness, eating quality attributes and transit-related damage (e.g. skin blackening, bruising, scuffing etc.). Sampling involved 24 fruit per clamshell treatment, 25 fruit per Euro-pack treatment (five fruit/replicate from both layers) and 30 fruit per carton treatment (two top, middle and bottom fruit /replicate). As each treatment reached a mean eating firmness of 2.0–2.5 lb it was transferred to a 34°F cold room.

Consumer tests in Raleigh NC

The consumer test involved 122 people of which 68% were female and 62% were aged between 25 and 55 years old. The panelists evaluated fruit from cartons that were warmed from cold for three days or ERC-conditioned for 1, 3 or 5 days, and fruit from Euro-packs that were conditioned for a day at 68°F with ERCs or in a trailer with a forced circulation of air containing 1000 ppm ethylene.

Just prior to the start of the consumer test, all the fruit from these six treatments that were to be tasted were removed from the cold room, pressure-tested at one location on the fruit and then sliced longitudinally into eight uniform pieces. Each person tasted a slice of cold fruit from each treatment and scored it for flavor, texture and overall liking on a 0 (dislike) to 10 (really like) scale.

Results and Discussion

ERC-conditioning of fruit in cartons and Euro-packs sealed in a plastic pallet cover

A half-pallet load of 'Green Anjou' in standard Euro-packs and cartons was effectively conditioned when sealed within a plastic pallet cover containing ERCs and allowed to warm up at ambient temperature for five days. The air temperatures at a central location within the covered pallet ranged between 50 and 66ºF. Oxygen and CO_2 levels were 12% and 8.5% respectively after five days. When the cover was removed, the conditioned fruit were ready to eat after a further 7 days of ripening (Figure 1). In contrast, the untreated fruit sealed within a plastic cover remained hard (12 lb mean firmness) throughout the two week test period at 68-70°C.

The concentration and distribution of ethylene within the load was not a limitation. Ethylene permeated evenly through the packages within about 24 hours from the start and remained between 247 and 126 ppm within a lower tier carton over the following four days. Previous studies (Chen et al. 1996, Facteau and Mielke 1998) indicated that 100 ppm ethylene is sufficient to condition early season 'Green Anjou' in 4 days at 68ºF and have them ready to eat with a further 7 days of warming.

There were no significant differences in the corrected mean firmness and rate of softening between fruit in the bottom four layers of boxes in the pallet. In contrast, fruit in packages in the top layer, with the greatest surface areas exposed to the outside, warmed faster and therefore softened more rapidly than those in the lower layers. These differences might be reduced by adding an extra layer of insulation on top of the pallet. There could also be some advantage in allowing fruit on pallets to warm up for a few days prior to ERC-conditioning under the plastic cover.

ERC-conditioning fruit in single clamshells, Euro-packs and standard cartons, trucked to Raleigh

We had aimed to cool the packages rapidly below 45ºF as soon as the fruit had been conditioned for 1, 3 or 5 days at ambient temperature. Unfortunately this was not achieved. Mean fruit temperatures in the different pack types during pre-transit cooling and trucking were 52-60°F and 42-53°F respectively (Table 1). Our 2004 trials indicated that pears in the presence of ethylene condition to some extent at temperatures of 45ºF or more. The truck atmosphere on arrival contained 2 ppm ethylene. Immediately after removal from the truck, ERC-treated packages, with the ERCs still in place at 10-14 days after their introduction, contained 3-9 ppm ethylene. This compared with 0.2-1.3 ppm ethylene in boxes of fruit conditioned in the trailer or just warmed. Thus fruit in all the packages containing ERCs were exposed to effective conditioning for considerably longer than the intended 1-5 days, including some in-transit conditioning. Not surprisingly, there was a major decrease in fruit firmness between the intended end of conditioning and arrival of fruit in Raleigh (Fig. 2). Some ERC treatments were ready to eat within two days after arrival in Raleigh (Fig. 2).

Table 1. Temperature logging using i-Button® temperature loggers amongst the fruit within representative packs of the various types throughout the various stages of the trial.

	Mean temperatures (°F) within packs						
	During conditioning			**Pre-transit cool storage for 4 days in Wenatchee WA**	**During refrigerated trucking to Raleigh NC for 4.5 days**	**During first 24 h ripening at 71.6ºF in Raleigh NC**	**During first 24 h after transfer to cold room. in Raleigh**
Container	**1 day**	**3 days**	**5 days**				
Std carton	51.3	63.7	62.1	55.6	53.2	57.0	59.6
Euro-2 layer	61.5	64.8	N.D.	59.9	48.8	53.4	53.3
Clamshell	N.D.	66.6	67.5	51.7	41.5	59.5	43.2

N.D. = not done

Heat transfer and thus cooling occurred more rapidly in clamshells and consequently fruit in this packaging was least affected by ethylene released by ERCs after the intended conditioning period. In contrast, fruit in standard cartons cooled more sluggishly and were therefore more receptive to ethylene during pre-cooling and in transit (Figure 2).

A Pear Bureau study (Good Fruit Grower, Sept 2005, p13) found that 79% of consumers expect pears to be ready-to-eat at purchase. Ideally, conditioned fruit must remain sufficiently firm to avoid any risk of bruising during shipping and distribution, but then must ripen rapidly at retail markets to develop juicy, flavorsome and aromatic qualities within a few days. Trial fruit that were conditioned for three or five days with ERCs in cartons all arrived at Raleigh at a mean firmness of less than 3 lb.

Euro-packs were better than cartons or clamshells for delivering ERC-conditioned fruit with minimal in-transit damage. Only 0.6% of conditioned fruit in Euro-packs was bruised on arrival at a mean firmness of 2.8 to 3 lb. In standard cartons, some in-transit bruising damage (3.3%) occurred in ERC-conditioned fruit that arrived almost ready-to-eat (2.2-5.2 lb mean firmness), but firmer fruit (7.6 lb mean on arrival) were undamaged and ripened to 2.9 lb mean firmness in five days at ambient temperature. Up to 16% of the fruit conditioned in clamshells had spin damage and blackening to the neck of the fruit, and damage increased as the mean firmness of fruit on arrival decreased. This was mostly due to the 90-count trial fruit fitting loosely in clamshell cavities designed for 80-count fruit.

As most of the industry packs fruit in cartons, an emphasis was placed on carton-conditioned fruit in the consumer test. Consumers were unable to detect a difference between fruit conditioned in cartons for 1, 3 or 5 days but preferred them to those that had been simply warmed in cartons for three days (Table 2). Fruit ERC-conditioned in Euro-packs for 1 day were preferred to fruit that had been pre-

warmed and ethylene conditioned in a trailer for 1 day. The latter were much firmer (mean 7.1 lb), having not ripened to an ideal eating firmness (1.7-2.3 lb) within the 5 days before tasting (Table 2).

Table 2. Mean scores from a consumer test involving 122 people who each tasted six slices of 'Green Anjou' pear that had been conditioned in different ways. Scores were based on a scale from 0 (dislike) to 10 (really like).

Conditioning treatment (68ºF) and period	**Range in firmness of fruit (lb)**	**Mean flavor score***	**Mean texture score***	**Mean overall score***
No artificial ethylene, simply warmed in cartons for 3 days	2.8 to 6.6 (mean 3.7)	5.6c	5.6c	5.3d
ERCs in cartons for 1 day	1.7 to 2.3	7.2a	6.7a	6.9a
ERCs in cartons for 3 days	1.7 to 2.3	6.8a	6.5a	6.4b
ERCs in cartons for 5 days	1.7 to 2.3	7.0a	6.8a	6.8ab
Commercial trailer with forced air warming/cooling and1000 ppm ethylene in Euro-packs for 1 day	5 to 9.2 (mean 7.1)	6.2b	5.9bc	5.9c
ERCs in Euro-packs for 1 day	1.7 to 2.3	7.1a	6.3ab	6.6ab

*Means in the same column, followed by the same letter, do not differ significantly at the 5% level.

All ERC-conditioned fruit gave significantly higher mean flavor and mean overall liking scores than the warmed controls that had received no ethylene or the trailer conditioned fruit. Texture scores were also significantly higher for the fruit in cartons with ERCs than in the controls (Table 2).

The trial results are consistent with a recent study on early season 'Comice' pears (Sugar and Basile, 2006) that revealed an increased capacity to ripen as the duration of ethylene exposure is increased. The ERC technology provides a potential alternative method to condition fruit without the need for a controlled conditioning room. This allows (1) longer-term conditioning at no extra cost (2) greater flexibility in coping with bottle-necks in the conditioning chain and (3) the possibility of conditioning individual pallet loads of packaged fruit taken directly from cold-storage.

Further work. We are proposing to further investigate the latter approach through a new project entitled "Conditioning in covered pallets by Ethylene Release Capsules".

References

Chen, P. M., Drake S. R., Varga D. M. and Puig, L. 1996. Precondition of D'Anjou pears for early marketing by ethylene treatment. Journal of Food Quality 19, 375.

Facteau, T. J. and Mielke, E. A. 1998. Proc. 7th International Symposium on Pear Growing. Acta Horticulturae, No 475, 567-574.

Sugar, D. and Basile, S. R. 2006. Ethylene treatment promotes early ripening capacity in mature 'Comice' pears. Horttechnology 16 (1), 89-91.

Acknowledgements

We thank Garry Williams and the staff of Bluebird in Peshastin and Wenatchee WA for their assistance in organizing pears, packaging, facilities and transport to enable these conditioning trials to be carried out. We also thank Gene Kupferman and his staff at WSU for their continued assistance and advice. We are especially grateful to MaryAnne Drake and staff at NCSU for the provision of excellent facilities and for expertly organizing and supervising the consumer test.

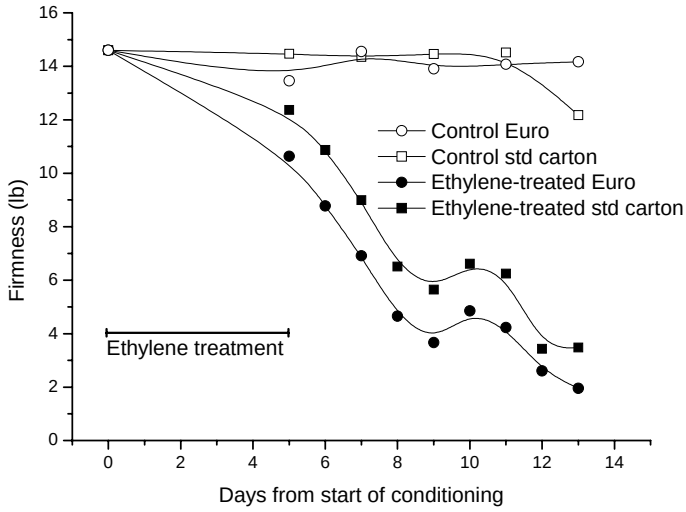

Figure 1. Effects of ERC conditioning in a covered pallet on subsequent fruit softening. Fruit in a mixed pallet of double layer Euro-packs and standard cartons were conditioned using ERCs placed on top of the pallet and sealed inside a plastic pallet cover to trap the ethylene. Control boxes were sealed in 80 µm plastic film (as used in the pallet cover) over the period of conditioning, but with no ERCs included.

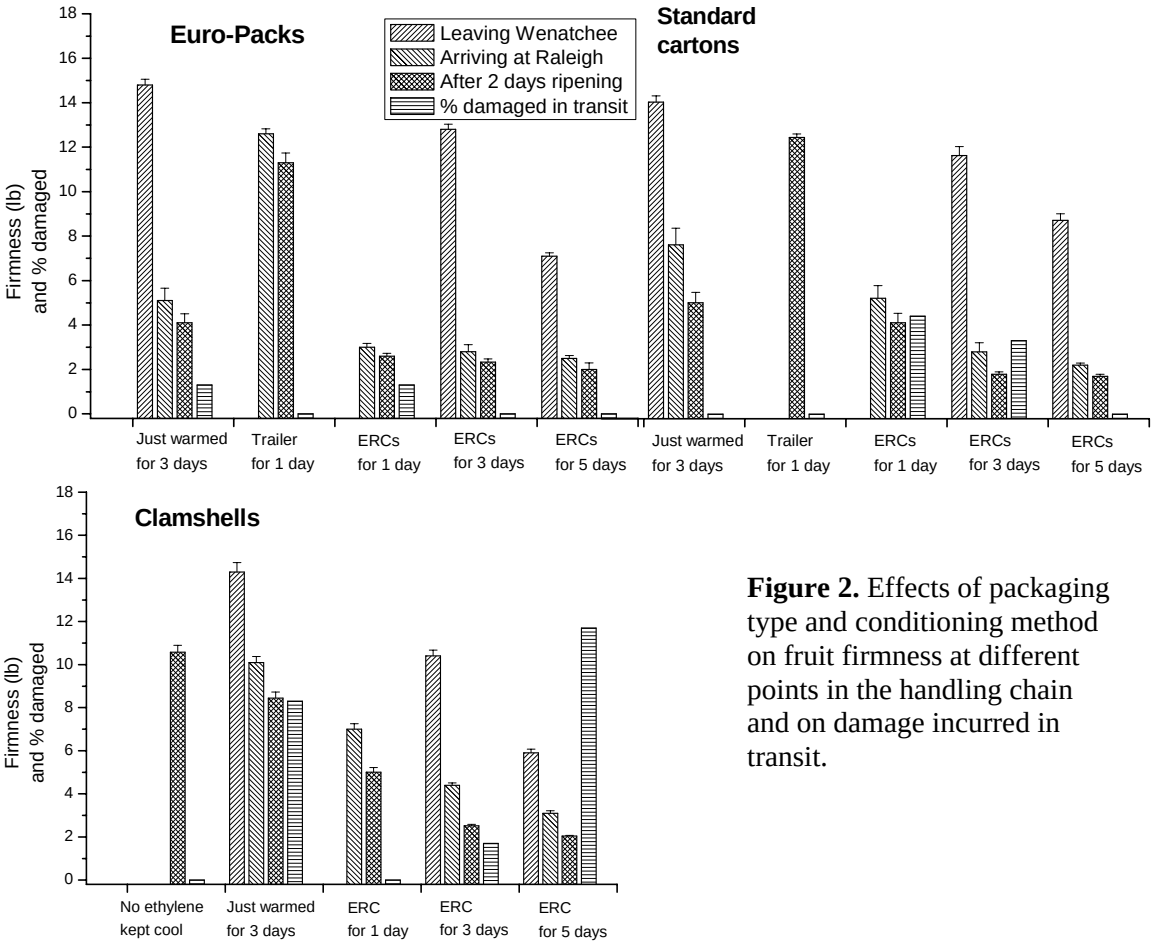

Figure 2. Effects of packaging type and conditioning method on fruit firmness at different points in the handling chain and on damage incurred in transit.

BUDGET

Year 1 (2003)	Year 2 (2004)	Year 3 (2005)	Project total (3 yrs)
$30,000	$49,900	$59,800	$139,700

Request for 2006: $0 for this project.