FINAL PROJECT REPORT

Project Title: Survey of Anjou pear conditioning in the Pacific Northwest

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Total Project Request: Year 1: $30,480

Other funding sources
None

Budget 1
Organization Name: WSU **Contract Administrator:** Katy Roberts
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Item	**2017**
Wages	$6,210
Benefits	$1,350
Equipment	$17,920
Supplies	$1,000
Travel	$3,500
Miscellaneous	$500
Total	$30,480

Footnotes: Wages for 0.5FTE for 3 months, Equipment for ethylene and CO2 meter, firmness meters, and temperature loggers.

Objectives
This project was a gap analysis on the pear conditioning programs in the Pacific Northwest, surveying current commercial conditioning programs to identify the current and desired performance of these programs. It also provided a platform for direct interaction with participating warehouses, and develop material in preparation for a pear conditioning workshop after the project's conclusion.

Significant Findings
There is a gap between the "current state" and "desired state" of Anjou ethylene conditioning at most warehouses. The reasons for this are typically because of: (i) time pressure to condition fruit to meet an order, (ii) lack of understanding of pear ripening physiology, and possibly (iii) not appreciating the impact of eating fruit (good or bad) on consumer buying habits. Inferior eating quality, especially earlier in the season, is a consequence of an inadequate ethylene conditioning treatment.

Ripening trailers and warm rooms have no airflow, and consequently fruit warming is slow and variable. This can be managed, to some degree, by extending the treatment duration to allow the pulp temperature to reach a minimum of 60°F before ethylene treatment. Modern ripening rooms provide adequate infrastructure to ripen pears, but management needs to take into account the fruit pulp temperature and the required duration of ethylene treatment for conditioning to be effective. Operators should take into account – and ideally measure – the maturity, air flow, pulp temperature, time of treatment, ethylene concentration, and relative humidity during ethylene conditioning treatment to achieve an effective treatment.

A half day pear session and facility tour will be included in the WSU Postharvest Fruit School (March 20-22).

Materials & Methods
Four warehouses in Washington and Oregon with ethylene conditioning facilities were included in the study between June and October 2017.
The different types of ethylene conditioning treatments were:

- ripening trailer
- warm room
- ripening room (older and new)

Ethylene, CO_2, and O_2 concentrations were measured with a Felix F-950 Gas Analyzer. Air speed was measured with a Kestrel 5200 environmental meter. Air temperature, relative humidity (RH), and pulp temperature (two probes per logger) were measured with Onset Hobo U-12 data loggers. These loggers were installed at six locations around each room. Fruit firmness was measured with a Mohr MDT-2 fruit firmness meter. Non-conditioned and conditioned fruit were kept at room temperature. Firmness was measured every second day until firmness began to drop, and then every day until firmness dropped below 1lb.

Results

Detailed results were shared with the participating warehouses during the project. Summary results are provided here.

Ethylene & CO_2

Disappointingly, the gas analyzer did not always complete logging during the ethylene conditioning treatment, but when logging did complete, the ethylene concentration maximum was greater than 100ppm, and CO_2 was approximately 0.5%. One issue noted with the ethylene generator is that the ethylene concentration peaked and then declined during the treatment. A comparison between an ethylene generator and direct supply from a cylinder of 5 or 10% ethylene would be interesting. The CO_2 concentration was below the recommended 1.0% limit. The installation of meters for both ethylene and CO_2 would improve monitoring and could aid management decisions. Note that these meters should be calibrated regularly according to manufacturers' guidelines to be useful.

Temperature, Time, Air flow, and Relative Humidity

Summary results from the four facilities are provided in Table 1 below. Note, none of the facilities had active relative humidity management.

Ripening Trailer: Operating on a 24 h warming, 24 h ethylene conditioning treatment, and post-treatment cooling outside the room, this treatment was not adequate to consistently condition fruit. Because of the lack of air movement and time rather temperature based approach, fruit were slow to warm up, never reaching 65°F and only having 7:30 h above 60°F. The temperature variation was high and the relative humidity low (71%).

Warm Room: This facility used experience and pulp temperature to decide on an ethylene conditioning treatment and achieved an effective conditioning treatment. Time to warm the fruit was 39:00 – *i.e.* approximately 24 h longer than a modern ripening room, but fruit spent 32:30 h above 65°F. Temperature variation was high and relative humidity low (64%).

This approach has a low capital and operating cost, but treatment took almost 4 days (excluding post-treatment cooling) so capacity is limited, and it is relatively inflexible in terms of sales lead times – which could result in inadequate conditioning if the operator is not disciplined.

Ripening Room 1: This older ripening room has potential to adequately ripen pears, with adequate air flow to quickly warm and cool fruit, and minimize pulp temperature variation. The average time to warm fruit varied between 12:40 and 19:20 when fruit were loaded at approximately 35°F pulp temperature. The time above 60°F and 65°F pulp temperature improved after discussion with the operator (from 20:20 to 29:20 h above 60°F and 0:00 to 11:00 h above 65°F), but was still inadequate to ensure a consistent conditioning treatment. Pulp temperature was usually less variable than the trailer and warm room because of the forced air through each pallet. RH was higher (79-89%), but still below the recommended 90-95%. This facility could improve operations by moving from a time-based approach to a fruit-based approach, taking into account the pulp temperature of the fruit during the conditioning treatment, and have a longer lead time to adequately condition fruit – *i.e.* move away from spot conditioning to a conditioning program with customers.

Ripening Room 2: This new ripening room had near textbook results, with adequate air flow, 25:40 h above 60°F and 22:00 h above 65°F. Temperature variation was low, except for the pallets next to the door – which leads to a refrigerated corridor. Relative humidity was low (81%) – with could be problematic with regards to fruit shriveling. This could be exacerbated by rapid cooling of the fruit with a large difference between air and pulp temperature. Fruit began to show slight shrivel at the neck when mass loss was about 4% from the start of the ethylene conditioning treatment.

Table 1: Environmental conditions during ethylene conditioning treatments at four facilities, along with the Pear Handling Manual Recommendation.

	Manual Recommendation	Trailer	Warm Room	Ripening Room 1*	Ripening Room 2
Airflow (fpm)	-	0	0	453 532 551	122 ⁋
Time to Warm (h:m)	-	24:00 #	39:00 § #	12:40 19:20 15:50	11:30
Time above 60°F Pulp Temperature (h:m)	-	7:30	53:00	20:20 20:50 29:20	25:40
Time above 65°F Pulp Temperature (h:m)	24	0:00	32:30	0:00 4:40 11:00	22:00
Duration of ET (h)	24	24 #	43:00 #	24 24 24	24
Pulp Temperature during ET (°F)	65 ± 5	54 – 64	59 – 68	56 – 62 50 – 64 60 – 65	57 – 65
Relative Humidity (%)	90-95	71	64	85 79 89	81

* Surveys done 3 times in different rooms.
§ Pulp temperature started at about 45°F and continued to warm.
# No temperature control; figure is from loading to start of ethylene treatment.
⁋ Spot measurements before treatment were about 450 to 500 fpm.

Fruit Quality

When the conditioning treatment was adequate, the eating quality of conditioned fruit was far superior with fruit having a buttery juicy texture and good flavor at a higher firmness level than non-conditioned fruit. These results are entirely expected, but reinforce that ethylene conditioning results in pears with superior eating quality sooner. This provides convenience and superior eating experience for consumers, but there is a risk of fruit quality loss from scuffing, bruising, and general shrink so warehouses, distribution centers, and retailers may need to adapt handling protocols to minimize waste.

The Mohr MDT-2 is well-suited to measuring pear firmness because it measures flesh firmness from the skin to the core, and measures crispness (for pears the loss thereof). Although this unit is more expensive than a typical benchtop electronic fruit firmness meter, it provides more valuable information on fruit quality and it can also be used on apples to amortize the capital cost.

Discussion

Inadequate facilities (ripening trailer or warm room) can be managed to some degree by having a longer treatment duration because of slower fruit warming. Trailers are more difficult to manage because access to all but the front two pallets is impossible with typical loading, and I recommend

warehouses discontinue using ripening trailers. Access to fruit in warm rooms is possible, so pulp temperature around the room can be measured to inform management decisions.

Modern ripening rooms provide adequate infrastructure to ripen pears, but recommended minimum standards still need to be achieved for the ethylene conditioning treatment to be effective. This is easily achieved by monitoring pulp temperature and adjusting the treatment accordingly. "Spot conditioning" to an order is not conducive to effective ethylene conditioning and delivery of fruit with good eating quality because it typically results in an inadequate ethylene treatment from low pulp temperature and/or inadequate treatment duration. Considering the cost of ripening rooms, it is recommended that, if possible, warehouses work towards a conditioning program with their customers to supply fully conditioned fruit that will ripen with good eating quality. The pear industry needs to align with other ripened fruit (e.g. kiwi fruit, tomatoes and especially bananas and avocados) to supply a greater proportion of conditioned or ripened fruit to encourage repeat consumption and more super consumers. This may require a shift to more protective packaging to reduce scuffing, bruising, and shrink but such innovations are required to drive growth in pear consumption and rejuvenation in the pear industry in the US.

The adage, "you can't manage what you can't measure" is apt for pear conditioning. As such, the acronym "**MATTER**" (Maturity, Air flow, Temperature, Time, Ethylene and Relative humidity) is a good reminder of important factors to measure and manage during ethylene conditioning.

The recommendations for ethylene conditioning in the Pear Handling Manual are adequate to ripen Anjou pears. Two questions that still need to be answered are: (i) 'What is the minimum ethylene conditioning treatment duration for early, mid- and late season fruit?' and 'Can 1-MCP-treated Anjou fruit ripen completely with an effective ethylene conditioning treatment?' Potential avenues for future research and extension are:

- Refinement of the temperature, treatment duration, and ethylene concentration for different maturity levels, storage duration, and 1-MCP treatment,
- Minima and maxima for air flow and relative humidity to determine if these parameters have an appreciable effect on shrivel and eating quality.
- Standards for cooling of conditioned fruit to minimize firmness loss and shrivel.
- Refinement of maturity beyond firmness, possibly looking at dry matter.
- Use of ethylene gas vs an ethylene generator to maintain the ethylene concentration at 100ppm.

Executive Summary

This survey revealed that there is a gap between the 'current state' and 'desired state' at most warehouses that are conditioning fruit. The desired state being the recommendations provided in the USA Pears' Pear Handling Manual. The reasons for this are typically because of: (i) time pressure to condition fruit to meet an order, (ii) lack of understanding of pear ripening physiology, and possibly (iii) not appreciating the impact of eating fruit (good or bad) on consumer buying habits.

Facilities with poor air movement (trailers and warm rooms) have no air flow, resulting in slow and variable warming of the fruit. The facility using the **ripening trailer** achieved a weak ethylene conditioning treatment because pulp temperature was only above 60°F for 7:30 hours and 0:00 hours above 65°F in a 24 h period. The facility that used a **warm room** conditioned the fruit for almost 4 days, achieving an effective conditioning treatment (32:30 hours above 65°F).

Facilities with **forced air ripening rooms** had adequate air flow through the pallets (450 - 550 fpm) with faster warming and less variable pulp temperature. One facility did not allow the fruit to reach a minimum pulp temperature before treating with ethylene resulting in a weak ethylene conditioning

treatment (20 – 29 hours above 60°F and 0 – 11 hours above 65°F), but did improve over the duration of the survey. One facility did follow the Manual's recommendation and achieved an effective ethylene conditioning treatment by treating with ethylene for 25:40 hours above 60°F and 22 hours above 65°F pulp temperature.
When the conditioning treatment was adequate, the eating quality of conditioned fruit was superior with fruit having a buttery juicy texture and good flavor at a higher firmness level than non-conditioned fruit.

The acronym "**MATTER**" (Maturity, Air flow, Temperature, Time, Ethylene, and Relative humidity) is a good reminder of important factors to measure and manage during pear ethylene conditioning.

Recommendations for further research are for (i) refinement of the temperature, time, and ethylene concentration, for different maturity levels and storage duration and 1-MCP treatment, (ii) minima and maxima for air flow and relative humidity, (iii) standards for cooling of conditioned fruit, (iv) comparison between ethylene gas and ethylene generator, and (v) refinement of maturity indices for pears.