FINAL PROJECT REPORT

Project Title: Delivering quality pear fruit to consumers

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Other funding sources: none

Total Project Funding: **Year 1:** $25,725 **Year 2:** $26,390 **Year 3:** $27,073 **Year 4:** $0

Budget History:

Item	**2015:**	**2016:**	**2017:**	**2018:**
Salaries	13,088[1]	13,481	13,885	0
Benefits	1,250[2]	1,300	1,352	0
Wages	6,715[3]	6,917	7,124	0
Benefits	672[4]	692	712	0
Equipment				
Supplies	3,500[5]	3,500	3,500	0
Travel	500[6]	500	500	0
Plot Fees				
Miscellaneous				
Total	25,725	26,390	27,073	0

Footnotes:
[1]Postdoctoral Research Associate: 1/3 FTE. 3% increase is factored into Year 2 and 3.
[2]OPE: 1/3 FTE. 4% increase is factored into Year 2 and 3.
[3]Wages: 500hr for a Biological Science Tech. at $13.43/hr. 3% increase is factored into Year 2 and 3.
[4]OPE: 10% of the wage, with a 3% annual increase.
[5]Supplies: maintaining cold rooms, buying fruit, gases (helium, nitrogen, hydrogen, air, and standard gases), and gas tank rental, and chemicals.
[6]Travel: field trips to packinghouses and orchards.

OBJECTIVES:

1. Elucidate the cell metabolic mechanisms and pre/postharvest factors affecting the development of buttery-juicy melting texture (BJMT) during ripening of pears.
2. Study pre/postharvest factors influencing the chilling requirement for ripening capacity (CRRC) of pears.
3. Develop conditioning protocols for 1-MCP treated Anjou pear.

SIGNIFICANT FINDINGS

1. Elucidate the cell metabolic mechanisms and pre/postharvest factors affecting the development of BJMT during ripening of pears.

a. ***Cell wall pectin metabolism.*** Water-soluble pectins (WSP), CDTA-soluble pectins (CSP), and pectin methylesterase (PME) were positively correlated with BJMT. WSP are hygroscopic and give consumers the BJMT feeling when eating pear.

b. ***Ethylene.*** The expression of *PcACO1* gene triggers ethylene synthesis and is associated with pectin metabolism.

c. ***BJMT index.*** BJMT index was developed to identify BJMT of pears based on extractable juice (EJ, mL $100g^{-1}$). BJMT index = (100 - EJ) / 10.

d. ***Factors affecting the development of BJMT***

1) ***Harvest maturity***. Anjou pears harvested at 15-14 lbs have an excellent BJMT and flavor after 4-7 months of regular-air (RA) storage at 30 °F plus 7 d at 68 °F, while pears harvested at 13-12 lbs have inferior BJMT and inferior flavor.

2) ***1-MCP + ethylene***. 150 ppb 1-MCP-treated Anjou pears (15-14 lbs) fail to develop BJMT following 8 months of RA storage plus 7 d at 68 °F. However, 1-MCP (150 ppb) + ethylene (150 ppb)-treated pears develop BJMT after 8 months of RA storage followed by 7 d at 68 °F.

3) ***Storage temperature***. Anjou pears stored at 30-32 °F develop BJMT in 5-7 months. Higher storage temperature, such as 34 °F, accelerate the development of BJMT; fruit stored at this temperature show increased development of superficial scald.

4) ***Controlled atmosphere (CA) storage***. Anjou pears develop an excellent BJMT after 3-8 months of regular CA (~1.5% O_2 + < 0.05% CO_2) or 3-10 months of low-O_2 CA (~0.8% O_2 + < 0.05% CO_2) storage at 30 °F plus 7 d at 68 °F.

2. Study pre/postharvest factors influencing the CRRC of pears.

a. ***Accumulated cold units (ACU*** *= hours < 50 °F during 42 d prior to harvest****) and Harvest maturity.*** On an orchard specific basis, ACU (0-300) affected CRRC when Anjou pears were harvested at 13-15 lbs. Higher ACU reduced CRRC. Harvest maturity also affected CRRC with more mature fruit generally having lower CRRC. Neither of these trends held across growing districts.

b. ***Ca content.*** Orchard elevation does not affect uptake of Ca in peel or pulp tissue. Six applications of 0.45% (w/v) $CaCl_2$ from 30 days after full bloom (DAFB) to 130 DAFB increased Ca absorption, and extended CRRC for ~10 d.

c. ***Temperature and ethylene conditioning.*** High ethylene exposure (100 ppm) with high storage temperature reduced CRRC and caused BJMT in the early ripening test. Fruit held at 68 °F and treated with 100 ppm ethylene for 72 h experienced elimination of CRRC, and

significant softening. These pears failed to develop a dessert quality comparable to chilled fruit.

3. Develop conditioning protocols for 1-MCP treated Anjou pear.

a. Late-harvested Anjou pears treated with 1-MCP-treated were able to ripen with minimal scald.
b. 300 ppb 1-MCP combined with 300 ppb ethylene improved ripening capacity (RC) of Anjou pears after long-term CA storage (i.e. > 7-8 months).

METHODS

Objective 1. Lab procedures were developed to quantify cell wall total pectin substances (TPS), WSP, CDTA-soluble pectin (CSP), and sodium carbonate-soluble pectin (SSP). Polygalacturonase (PG) and pectin methylesterase (PME), key enzymes regulating the pectin degradation process, were monitored. Anjou pear fruit harvested at commercial maturity was ripened for 7 d at 68 °F after storing at 30 °F for 0, 1, 2, 3, 4, 5, 6, 7, or 8 months in RA. Tissue samples were frozen in liquid N_2 and stored at -80 °C until analysis. The effects of harvest maturity (FF = 15-12 lbs), 1-MCP+ethylene, storage temperatures (30, 32, and 34 °F), and CA storage on cell wall pectin metabolism and buttery-juicy texture development were studied. An industry standard methodology was developed to objectively quantify the buttery-juicy texture.

Objective 2. Pears were sampled from 10 orchards in the North Central WA, Mid-Columbia, and Southern OR growing districts on several dates over two seasons. The orchards ranged in elevation from 540 ft to 1890 ft. A total of 44 samples were collected for this study.

Objective 3. To facilitate early marketing of 1-MCP treated Anjou pears, commercially feasible conditioning protocols were developed to ensure that conditioned fruit with ripening capacity had optimal shipping firmness and post-conditioning storage life. Conditioning parameters included ethylene conditioning, intermediate temperature conditioning, and ethylene + intermediate temperature conditioning.

RESULTS

Elucidate the cell metabolic mechanisms and pre/postharvest factors affecting the development of BJMT during ripening of pears.

a. Cell wall pectin metabolism. Anjou pears harvested at 15-14 lbs from MCAREC showed no RC expressed by fruit firmness following 1-3 months of RA storage at 30 °F plus 7 d at 68 °F. These pears began to soften below 5 lbs after 4 months of storage and developed excellent BJMT. However, coarse and dry texture was observed after 8 months of RA storage during the ripening test (Fig. 1). The development of BJMT was negatively correlated with RC, but was positively correlated with WSP, CSP, or PME (Table 1). No relationship between BJMT and TPS, SSP, or PG was observed at any length of storage period.

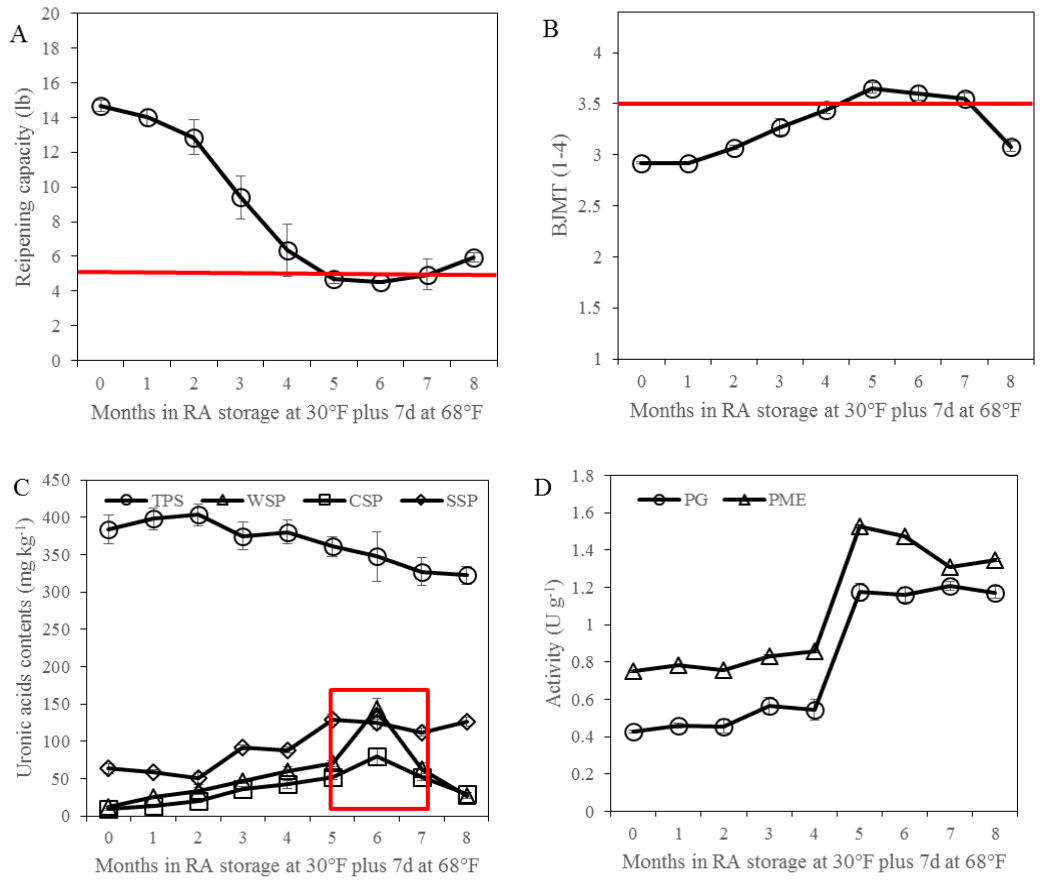

Fig. 1. Ripening capacity (RC) expressed by fruit firmness (A); BJMT (B); total pectin substances (TPS), water-soluble pectin (WSP), CDTA-soluble pectin (CSP), sodium carbonate-soluble pectin (SSP) (C); polygalacturonase (PG), and pectin methylesterase (PME) (D) of Anjou pears following 8 months of RA storage at 30 °F plus 7 d at 68 °F.

Table 1. Correlation analysis among RC, BJMT, TPS, WSP, CSP, SSP, PG, and PME.

	RC	BJMT	TPS	WSP	CSP	SSP	PG	PME
RC								
BJMT	**-0.909****							
TPS	0.781*	-0.488						
WSP	-0.691*	**0.919****	-0.366					
CSP	-0.863**	**0.818****	-0.562	0.953**				
SSP	-0.396*	0.299	-0.866**	0.599	0.368			
PG	-0.001	0.001	0.727*	0.074	-0.130	-0.348		
PME	-0.859**	**0.668***	-0.501	0.870**	0.724*	0.427	-0.486	

*, ** significant difference at P = 0.05 and 0.01 levels, respectively.

b. Ethylene. The *PcACO1* gene was a critical factor correlated with ethylene production. Ethylene synthesis triggered the development of RC and participated in pectin metabolism (Fig. 2).

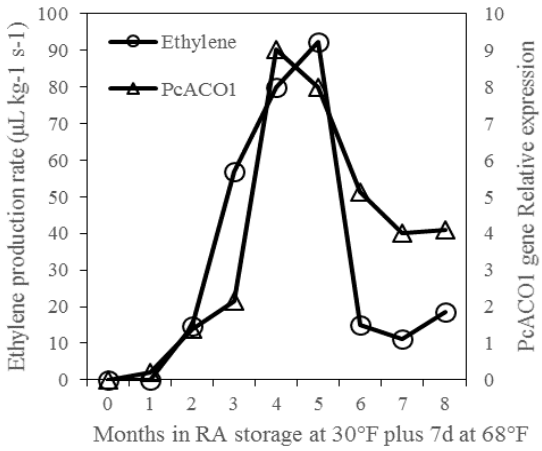

Fig. 2. Ethylene production rate and expression of PcACO1 gene of Anjou pears following 8 months of RA storage at 30 °F plus 1 d at 68 °F.

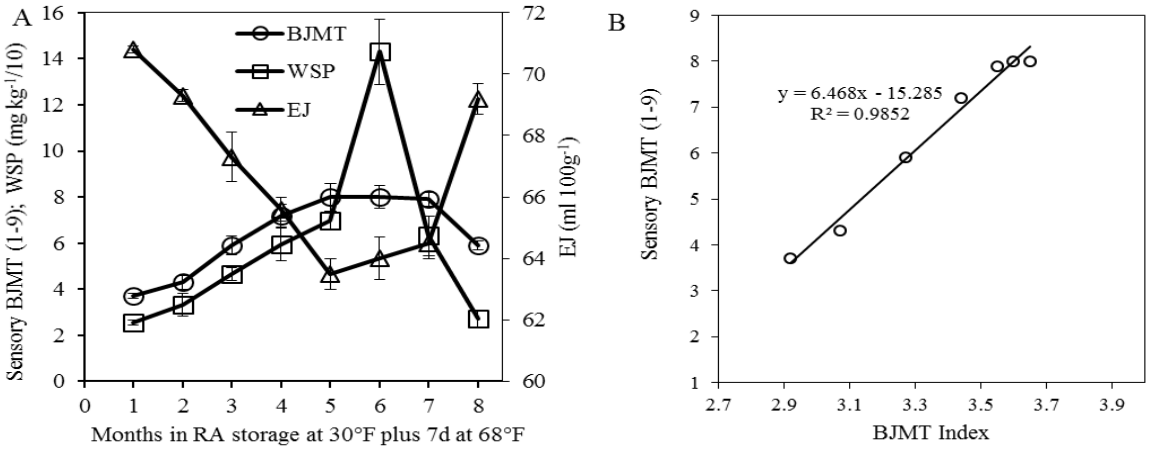

Fig. 3. BJMT, WSP, and extractable juice (EJ) (A) and the correlation of BJMT index with sensory BJMT scores (B) of Anjou pears following 8 months of RA storage at 30 °F plus 7 d at 68 °F.

c. Factors affecting the development of BJMT.

1) ***Harvest maturity***. In 2016, Anjou pears were harvested at 15-11 lbs from MCAREC. Flesh firmness for H1 was 14.7 lbs; for H2, 12.8 lbs; for H3, 11.2 lb. H2 or H3 pears developed a BJMT after 2-4 months of RA storage at 30 °F followed by 7 d at 68 °F. By contrast, H1 pears developed BJMT after 4-6 months under the same storage conditions. Flesh firmness in H2 and H3 was below 5 lbs following 4-6 months of RA at 30 °F plus 7 d at 68 °F, resulting in a coarse and dry texture in both H2 and H3 pears, as well as a dramatic reduction of WSP (Fig. 4).

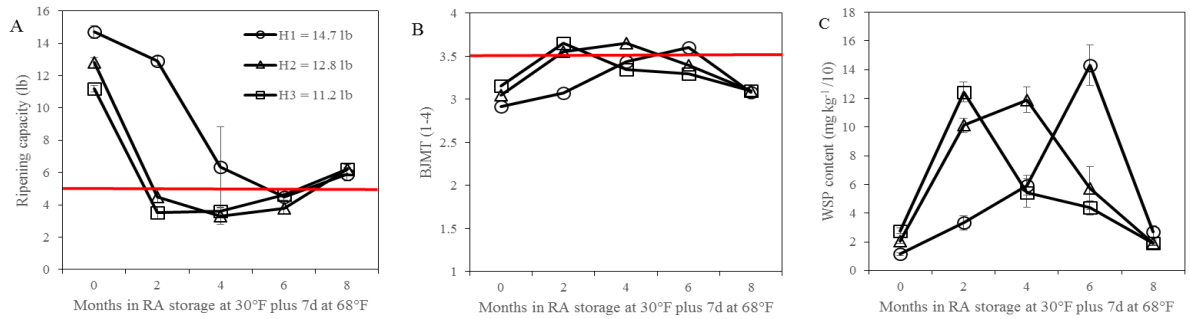

Fig. 4. RC (A), BJMT (B), and WSP (C) affected by harvest maturity of Anjou pears at MCAREC following 8 months of RA storage at 30 °F plus 7 d at 68 °F.

2) Assessments of RC and BJMT indicated that Anjou pears harvested from MCAREC at 15-14 lbs developed BJMT after 5-7 months of RA storage at 30 °F plus 7 d at 68 °F. 1-MCP-treated pears failed to develop BJMT over the whole of the storage period, while 1-MCP combined with ethylene recovered RC and developed BJMT at higher WSP levels after 8 months of RA storage at 30 °F plus 7 d at 68 °F (Fig. 5).

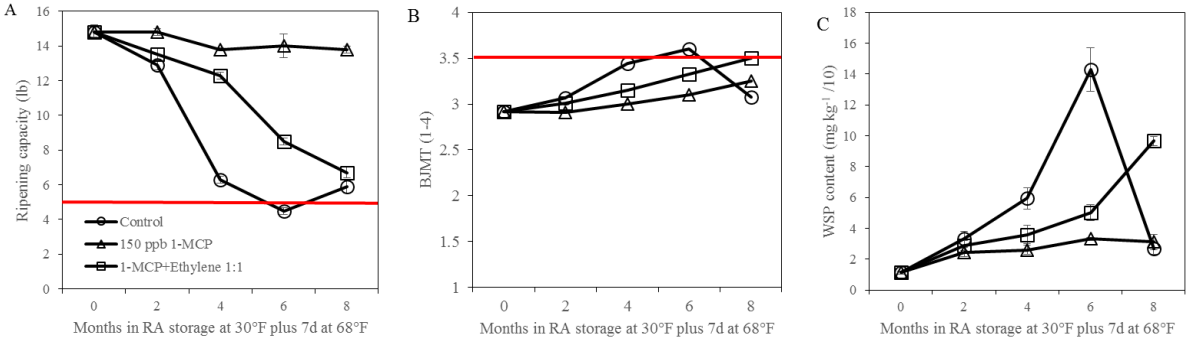

Fig. 5. RC (A), BJMT (B), and WSP (C) in Anjou pear treated with 150 ppb 1-MCP alone or with a combination of 150 ppb 1-MCP plus 150 ppb ethylene of Anjou pears following 8 months of RA storage at 30 °F plus 7 d at 68 °F.

3) Although Anjou pears harvested at 15-14 lbs developed BJMT after 5-7 months of storage at 32 °F, these fruit had a higher incidence of superficial scald during ripening. After 4 months of 34 °F, fruit had developed BJMT, indicating that the higher storage temperature can promote ability to ripen. The most effective storage temperature for Anjou pears appeared to be 30 °F (Fig. 6).

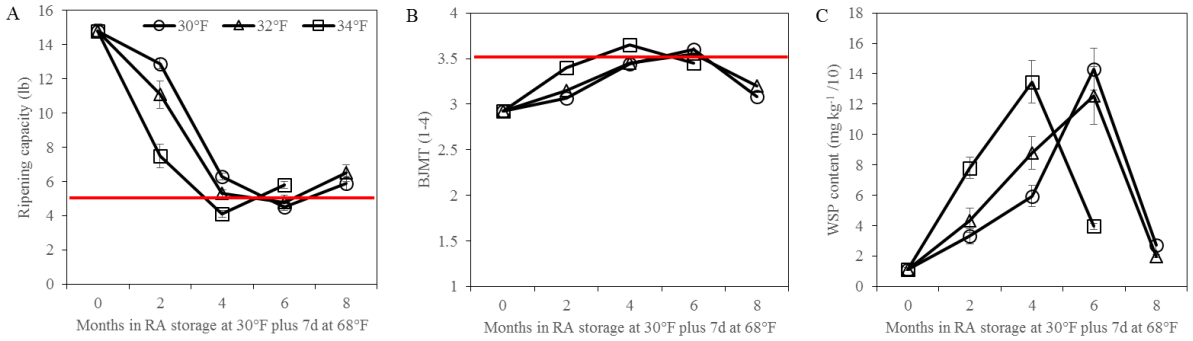

Fig. 6. RC (A), BJMT (B), and WSP (C) affected by storage temperature of Anjou pears following 8 months of RA storage at 30 °F plus 7 d at 68 °F.

4) ***CA storage.*** Anjou pears were harvested from MCAREC at 15-14 lbs and subjected to regular CA; these pears developed BJMT during 3-8 months of storage at 30 °F plus 7 d at 68 °F. Further, pears subjected to low-O_2 CA developed longer-lasting BJMT and maintained higher WSP than regular CA- or RA-treated pears. Decreasing O_2 to 0.8% extended the life of the BJMT quality. (Fig. 7).

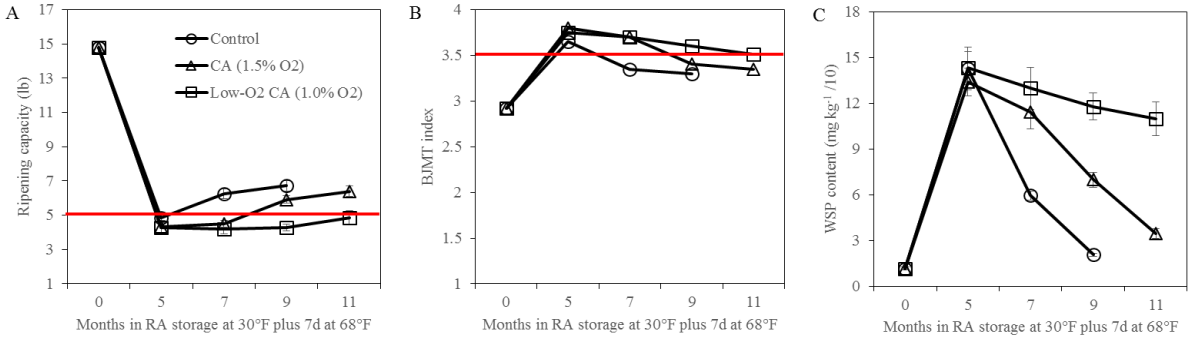

Fig. 7. RC (A), BJMT (B), and WSP (C) as affected by regular CA (~1.5% O_2 + < 0.05% CO_2) or low-O_2 CA (~0.8% O_2 + < 0.05% CO_2) of Anjou pears following 5, 7, 9, and 11 months of storage at 30 °F plus 7 d at 68 °F.

Study pre/postharvest factors influencing the CRRC of pears.

a. ACU and harvest maturity. In preliminary studies with fruit from the Hood River Valley harvested at ~15 lbs from altitudes of ~500 - 2,000 ft ACU ranged from 0 to 269 units. Fruit with ACU >200 units had significantly greater WSP and a significantly higher BJMT index (Fig. 8A and B). Production elevation and harvest maturity significantly influenced CRRC (Fig. 8C). Fruit from low elevation had higher CRRC than pears harvested from higher elevation at the same harvest maturity.

For the 44 fruit samples obtained over two seasons from 10 orchards in North Central WA, Mid-Columbia, and Southern OR, there was a slight trend toward decreased CRRC with higher ACU, however, this relationship was very weak (R^2=0.05). There was a slightly stronger trend toward decreased CRRC with more advanced maturity (R^2=0.14). These results indicate that, both ACU and harvest maturity were only weakly correlated CRRC, so

neither seems useful in modeling and predicting CRRC at harvest time across regions. For any single orchard in a given season, the relationship between ACU and CRRC was generally much stronger (R^2= 0.34 to 0.95), so ACU may be a useful indicator of CRRC on a site specific basis. As indicated above, orchard elevation can have an effect on ACU and consequently on CRRC. In the Hood River Valley, for example, a negative temperature gradient follows the north-south elevation gradient and generally results in higher ACU at higher elevation (R^2=0.81). The corresponding trend in CRRC with increased elevation, is however, much weaker (R^2=0.12). Together, these results indicate that additional factors must be considered in developing a predictive model for CRRC.

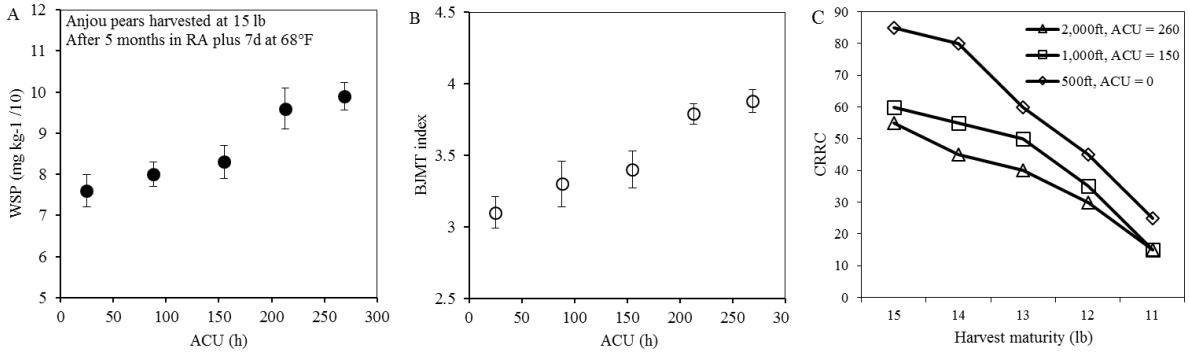

Fig. 8. WSP (A) and BJMT index (B) of Anjou pears from the Hood River Valley as affected by accumulated cold units (ACU) after 4 months of RA storage at 30 °F plus 7 d at 68 °F. Relationship between CRRC and harvest maturity (C) in Anjou pears.

b. ***Ca content.*** Anjou pears were harvested at ~13 lbs from five orchards with elevations ranging from ~500 - 2000 ft, and peel and pulp Ca content was measured. There were no significant differences in peel Ca content among the five orchards (Fig. 9A), although pulp tissues differed. There was no relationship between CRRC and Ca content in peel or pulp tissue (Fig. 9A and B). At MCAREC, we sprayed 0.45% (w/v) $CaCl_2$ 6 times at 20-day intervals from 30 DABF to 130 DAFB. These applications significantly increased Ca content in peel and pulp tissue at harvest and required longer CRRC (about 10 days) than untreated fruit (Fig. 9C).

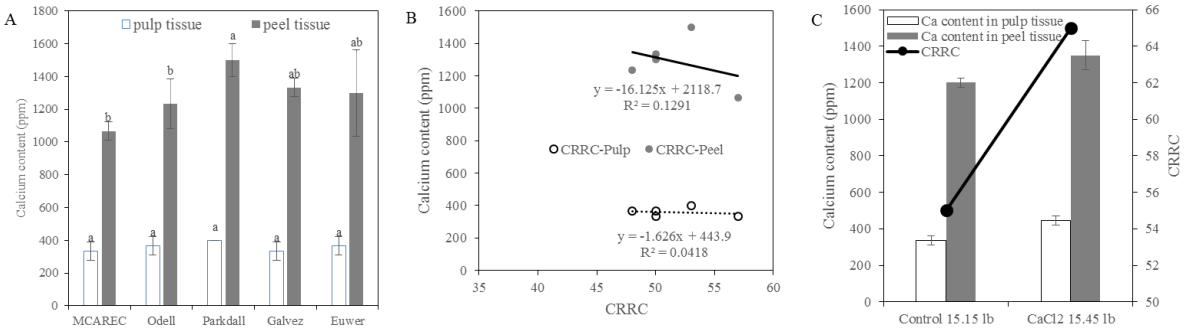

Fig. 9. Calcium content in pulp and peel tissue (A) of Anjou pears from five orchards in the Hood River Valley, OR. Relationship between calcium content in pulp or peel tissue and CRRC (B) in Anjou pears. Calcium content and CRRC (C) affected by $CaCl_2$ sprays to Anjou pears at MCAREC.

c. ***Temperature and ethylene conditioning.*** Anjou pears were harvested at 14 lbs and treated with 100 ppm ethylene at 68 °F for 24, 48, and 72 hr. After each 24 h period, fruit were removed and separated into two groups. One group was held at 30 °F, the other at 50 °F. As shown in Table 2, the longer the ethylene exposure duration, the shorter the CRRC required. In addition, the higher storage temperature reduced CRRC requirement. Ethylene at 100 ppm for 72 hrs can eliminate CRRC, but the ethylene-treated fruit did not develop dessert quality.

Table 2. CRRC in Anjou pears condition in 100 ppm ethylene for 0, 24, 48, 72 h at 68 °F followed by temperature condition at 30 °F or 50 °F.

Ethylene conditioning duration (h)	Condition temperature (*°F*)	
	30	50
0	65	15
24	30	5
48	10	5
72	0	0

<u>Develop conditioning protocols for 1-MCP treated Anjou pears.</u>

a. ***Late-harvest pears treated with 1-MCP.*** Late-harvested fruit are prone to loss of firmness and green color during storage. These pears are more susceptible to superficial scald after removal from RA storage and develop a coarse and dry texture at ripening. Fruit mature faster on the tree in hot seasons; labor shortages in recent years have resulted in fruit being harvested at over-mature stages with reduced storability. In this study, late-harvest pears treated with 150 ppb 1-MCP at LM1 and LM2 developed BJMT and less superficial scald compared to untreated fruit after 6 months of RA storage at 30 °F plus 7 d at 68 °F (Table 3).

Production elevation influenced the effect of 1-MCP on later-harvested fruit (Table 4). Pears produced at 688 ft, harvested at FF ~12.5 lbs, and treated with 1-MCP developed BJMT after 7 months of RA storage at 30 °F plus 7 d at 68 °F. Pears produced at 1752 ft and treated with 1-MCP failed to develop BJMT after 7 months, but RC decreased dramatically and these pears tended to achieve RC after long-term storage.

Table 3. Changes in RC, soluble solids content (SSC), titratable acidity (TA), BJMT, and superficial scald (SS) of commercial maturity (CM) and late-harvest maturity (LM1 and LM2) Anjou pears on day 7 at 20 °C as affected by 150 ppb 1-MCP following storage at –1.1 °C for 4 and 6 months.

Harvest periods	Treatment	Storage period (months)	RC (lbs)	SSC (%)	TA (meq. L^{-1})	BJMT (1-4)	SS (%)
CM – (14.8 lbs)	Control	4	4.9 ± 0.6 b	13.0± 0.2 a	33.88 ± 1.77 b	3.6 ± 0.2 b	5.7 ± 1.2 b
	Control	6	3.9 ± 0.4 c	13.0± 0.3 a	22.33 ± 1.17 d	3.8 ± 0.1 a	25.34 ± 3.7 a
	1-MCP	4	11.9 ± 0.6 a	13.1± 0.3 a	37.77 ± 1.39 a	3.2 ± 0.2 c	0 c
	1-MCP	6	11.6 ± 0.3 a	13.2± 0.5 a	25.03 ± 0.64 c	3.1 ± 0.2 c	0 c

LM1 – (12.8 lbs)	Control	4	3.3 ± 0.5 c	13.0 ± 0.2 a	28.97 ± 0.31 b	3.6 ± 0.2 a	11.9 ± 2.1 b
	Control	6	3.6 ± 0.4 c	13.2 ± 0.3 a	24.07 ± 0.31 c	3.5 ± 0.2 ab	40.3 ± 5.9 a
	1-MCP	4	8.3 ± 0.6 a	12.9 ± 0.3 a	31.34 ± 0.12 a	3.1 ± 0.2 c	0 d
	1-MCP	6	6.6 ± 0.2 b	13.3 ± 0.4 a	28.04 ± 0.25 b	3.4 ± 0.2 b	3.7 ± 1.0 c
LM2 – (11.2 lbs)	Control	4	3.6 ± 0.4 c	13.2 ± 0.3 a	25.69 ± 0.03 c	3.6 ± 0.2 a	32.5 ± 5.6 b
	Control	6	4.6 ± 0.3 b	13.3 ± 0.5 a	22.87 ± 0.11 d	3.5 ± 0.2 a	58.7 ± 7.9 a
	1-MCP	4	6.6 ± 0.3 a	13.1 ± 0.4 a	28.97 ± 0.51 a	3.4 ± 0.1 a	3.6 ± 0.6 d
	1-MCP	6	6.1 ± 0.5 a	13.4 ± 0.5 a	26.49 ± 0.34 b	3.5 ± 0.1 a	5.9 ± 1.3 c

Different letters indicate significant differences between treatments at each harvest period according to Fisher's protected LSD test at $P < 0.05$.

Table 4. Changes in RC, SSC, TA, BJMT, and SS of late-harvest Anjou pears on day 7 at 20 °C affected by 150 ppb 1-MCP and production elevation (Orchard 1 at 688 ft and Orchard 2 at 1752 ft) following storage at –1.1 °C for 5 and 7 months.

Production elevation	Treatment	Storage period (months)	RC (lbs)	SSC (%)	TA (meq. L^{-1})	BJMT (1-4)	SS (%)
Orchad1 – 688 ft (12.5 lbs)	Control	5	3.3 ± 0.2 c	13.1 ± 0.3 b	24.29 ± 0.83 b	3.7 ± 0.1 a	51.3 ± 4.5 b
	Control	7	3.7 ± 0.2 b	12.5 ± 0.2 c	22.15 ± 0.47 c	3.5 ± 0.2 ab	63.3 ± 7.2 a
	1-MCP	5	6.7 ± 0.4 a	13.5 ± 0.1 a	26.15 ± 0.99 a	3.3 ± 0.1 b	2.6 ± 0.6 c
	1-MCP	7	3.7 ± 0.3 b	13.1 ± 0.4 b	24.34 ± 0.02 b	3.6 ± 0.2 a	5.1 ± 0.5 c
Orchard2 – 1752 ft (12.6 lbs)	Control	5	3.0 ± 0.1 d	13.2 ± 0.4 a	23.67 ± 0.02 c	3.8 ± 0.2 a	55.0 ± 4.7 b
	Control	7	4.2 ± 0.1 c	12.3 ± 0.2 c	21.74 ± 0.51 d	3.6 ± 0.2 a	66.0 ± 5.5 a
	1-MCP	5	10.3 ± 0.2 a	13.1 ± 0.4 a	29.67 ± 0.78 a	2.8 ± 0.1 c	1.1 ± 0.2 d
	1-MCP	7	8.3 ± 0.3 b	12.7 ± 0.2 b	28.11 ± 0.34 b	3.2 ± 0.2 b	5.3 ± 0.3 c

Different letters indicate significant differences between treatments at each harvest period according to Fisher's protected LSD test at $P < 0.05$.

b. **Combination treatment of 1-MCP and ethylene in CA storage.** The 1-MCP+ethylene (1-MCP (300 ppb) + ethylene (300 ppb) treatment recovered the RC of Anjou pears after 8 months of CA storage. Untreated and ethylene-treated fruit developed RC following 4-8 months storage in CA storage at 30 °F plus 7 d at 68 °F (Fig. 10A). However, 1-MCP inhibited RC for 8 months. The combination treatment slightly increased SSC and inhibited the decline of TA during 8 months of CA storage (Fig. 10B and C). BJMT of untreated fruit decreased from 3.8 to 3.6 during 8 months

of storage. 1-MCP treated fruit had a BJMT lower than 2.7 during the same period of storage. The 1-MCP + ethylene treated fruit had excellent BJMT after 8 months of storage.

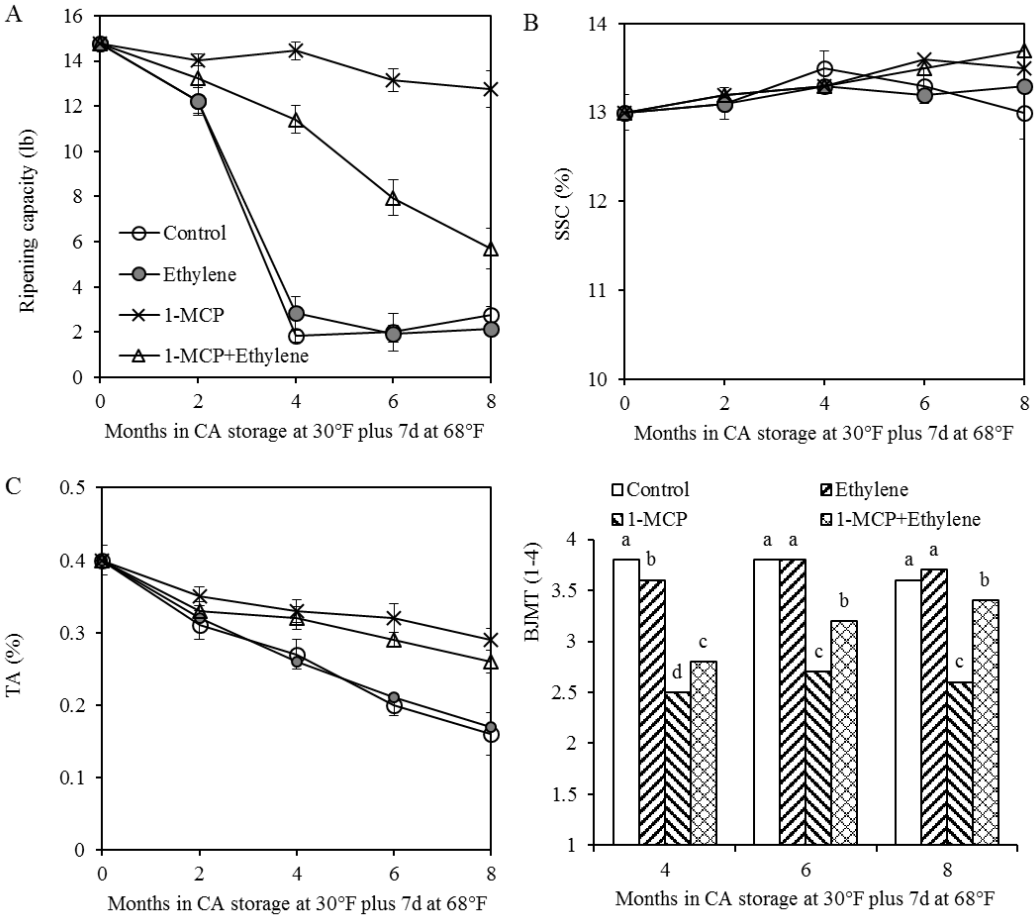

*Fig. 10. RC (A), SSC (B), TA (C), and BJMT (D) affected by 300 ppb 1-MCP and 300 ppb ethylene, alone or in combination with, in Anjou pears following 8 months of CA storage (*1.5% O_2 + < 0.05% CO_2*) at 30 °F plus 7 d at 68 °F.*

EXECUTIVE SUMMARY

Project title: Delivering quality pear fruit to consumers

European pears (*Pyrus communis* L.) are enjoyed by consumers when fruit have ripened to a buttery-juicy (melting) texture with full flavor development. However, after receiving the chilling requirement and/or ethylene conditioning, pear fruit can soften but may develop a dry-coarse (mealy) texture after ripening, especially those fruit harvested at later maturity stages or improperly stored. The lack of knowledge about the metabolic mechanisms resulting in buttery-juicy texture has precluded development of practical approaches to delivering fruit with this preferred texture, nor has any chemical or physical analysis been available for the industry to define the textural properties of ripened pears.

The current research indicated that water-soluble ponyuronides (WSP), CDTA-soluble pectins (CSP), and pectin methylesterase (PME) are positively correlated with the development of buttery-juicy melting texture (BJMT). WSP are hygroscopic and impart the BJMT feeling to the consumer. Measuring WSP is tedious, although extractable juice (EJ, mL $100g^{-1}$) is relatively simple to measure; EJ is negatively correlated with BJMT. An EJ-based index to score BJMT was developed: BJMT index = (100 - EJ) / 10. We used the new BJMT index to investigate how pre- and post-harvest factors affect the development of BJMT and concluded:

- Pears harvested at 15-14 lbs maturity had longer BJMT life for up to 8 months.
- Anjou pear harvested at 15-14 lbs and treated with 150 ppb 1-MCP failed to develop BJMT after 8 months of RA storage. Anjou pear harvested at 15-14 lbs and treated with 1-MCP + ethylene did recover ripening capacity and developed BJMT after 8 months.
- Higher storage temperature (i.e. 34 °F) accelerated development of BJMT, but this treatment was associated with higher incidence of superficial scald.
- Compared to regular CA conditions, decreasing the O_2 level to 0.8-1% at 30 °F extended BJMT life for an additional two months to as long as 11 months.

After pears achieve a minimum number of chilling days, they can develop acceptable ripening capacity. In the case of Anjou pears, the chilling requirement to reach reaching full ripening capacity varied significantly (50-90 d), and is influenced by pre- and post-harvest factors. From this, we conclude that:

- Accumulated cold units (ACU) affected the chilling requirement for ripening capacity (CRRC); higher ACU reduced CRRC.
- Harvest maturity also affected CRRC, with more mature fruit generally having lower CRRC. Neither of these trends held across growing districts.
- Ca levels affected the CRRC period. Pre-harvest Ca sprays increased CRRC by ~10 days.
- Storage temperature and ethylene conditioning affected CRRC periods, with higher storage temperatures and longer ethylene exposure reducing the time to reach CRRC.

Late-harvest at FF = 13-12 lbs enables complete ripening of the 1-MCP treated Anjou pears, while controlling superficial scald. A combination treatment of 300 ppb 1-MCP and 300 ppb ethylene improved the ripening capacity of Anjou pears after long-term CA storage (i.e. > 7-8 months).