FINAL PROJECT REPORT
WTFRC Project Number: PR-04-433

Project Title: Harvest and postharvest practices for optimum quality

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Budget History:

Item	Year 1: 2004	Year 2: 2005	Year 3: 2006
Salaries*	44,233	49,042	24,857
Benefits	13,270	14,712	12,243
Wages	0	0	0
Benefits	0	0	0
Equipment	0	0	0
Supplies	2,300	2,300	800
Travel	0	0	0
Miscellaneous	0	0	0
Total	59,803	66,054	37,900

*Salaries: 2004: GS-9 biological science tech., 2005: GS-11 Postdoctoral Research Associate, 2006: GS-11 Postdoctoral salary at 0.5FTE, the other 0.5FTE funding provided by ARS.

Objectives:

1. Identify additional indicators of physiological and/or horticultural maturity that are indicative of storability.

2. Identify protocols for 1-MCP use that ensure predictable ripening.

3. Characterize how pear fruit ripening and development of disorders are impacted by prolonged storage at the low O_2 limit.

Significant Findings 2004-2006:

- Additional measures of fruit firmness/texture may provide additional harvest maturity information.
- Changes in production of several volatile compounds by freshly harvested 'Bartlett' and 'd'Anjou' pears that correlate with optimum harvest date based on firmness are not consistent between lots.
- Ripening capacity of 1-MCP treated 'd'Anjou' pears increases with CA O_2 concentration and CA storage duration.
- Efficacy of 1-MCP can be reduced by sufficient ethylene or CO_2 present during treatment.
- Efficacy of post-storage 1-MCP treatment of 'Bartlett' pears may be dependent on ethylene present during treatment.
- Field application of 1-MCP can slow postharvest ripening of 'Bartlett' pears.
- The low oxygen limit for 'd'Anjou' pears defined by chlorophyll fluorescence is subject to seasonal variation.
- Impacts of 'Bartlett' and 'd'Anjou' storage at the low oxygen limit are cultivar and lot specific and dependent on storage duration.

Results and Discussion:

Indicators of maturity/storability.

Studies over the 3 year project period indicate considerable variability exists between seasons and lots within a season in the progression of fruit quality and physiological parameters analyzed as a function of fruit development. The focus of this objective was to evaluate potentially new means to assess maturity, and the main factors evaluated were non-ethylene, non-respiratory volatile production and additional measures of fruit physical properties. Although changes in volatile production during maturation were observed for both 'Bartlett' and 'd'Anjou, consistent differences across lots and seasons that could be useful as an additional measure of maturity were not apparent. Changes in emission of total or specific volatiles, most often esters, were apparent the week of or the week prior to optimum maturity (based on storage data) but the same patterns were not observed across lots and seasons. The same outcome was observed for analysis of another gas produced by fruit, nitric oxide (NO). While NO production tended to increase during fruit development, consistent changes in NO that may be of utility for maturity assessment were not observed.

Additional measures of fruit texture/firmness may have potential as indicators of storability. An instrument that records information for a number of physical aspects including firmness at multiple points to the core was used for this portion of the studies. A measure of firmness of the inner portion of 'd'Anjou' fruit (M2, 0.32"in to the coreline) in some instances showed changes in values from week to week that were not reflected in the firmness value for the outer portion of the fruit (M1, fruit surface to 0.32” in). Differences in M2 between lots with similar M1 values were observed as were differences between seasons. As both M1 and M2 values decrease as fruit soften, higher M2 values at harvest may be a factor influencing differences in storability between lots.

	August 11	August 18	August 25	September 1	September 8
Firmness lbs	19.6	19.1	19.0	16.1	15.8
Starch (1-6)	1	1	1	1.5	4.5
Ethylene (ppm)	nd	nd	nd	0.02	nd
Butyl acetate*	13.3	13	848	266	216
Pentyl acetate*	1.6	1.7	87	10.5	1
Hexyl acetate*	3.0	4.4	1879	314	0.14
total esters*	473	2090	4153	1232	1234
NO (nL $kg\ h^{-1}$)	nd	nd	nd	1.1	2.6

Table 1. Bartlett maturity 2004. NO: nitric oxide. *nM kg^{-1} m^{-3}

Orchard 1	August 3	August 9	August 15	August 22	August 29
Firmness lbs	15.7	14.9	12.4	13.1	12.1
Starch (1-6)	1.2	1.5	2	4.7	4.4
esters*	7	140	42	630	4250
aldehydes*	425	190	210	1080	2465
total detected*	530	335	260	1750	6870

Orchard 2	August 4	August 10	August 19	August 24	Sep 1
Firmness lbs	18.7	18.6	16.8	16.8	14.6
Starch (1-6)	1	1.1	1.1	1.2	1.5
esters*	400	625	555	70	1150
aldehydes*	12,500	755	4310	830	590
total detected*	13,430	1380	4880	920	1770

Orchard 3	August 5	August 15	August 22	August 29	Sep 6
Firmness lbs	19.7	17.4	16.7	18.2	17.4
Starch (1-6)	1	1.1	1	1.4	1.9
esters*	430	105	84	39	270
aldehydes*	5185	680	555	530	775
total detected*	5620	785	640	570	1050

Table 2. Bartlett maturity 2005. *nM kg^{-1} m^{-3}

Orchard 1 ‘04	August 22	August 30	August 22	August 29	September 6
M1 lbs	15.9	14.4	13.5	12.4	10.8
M2	18.8	18.1	15.8	14.6	14.3

Orchard 2 ‘05	August 18	August 24	September 1	September 8	September 15
M1 lbs	16.1	14.9	14.6	14.5	13.1
M2	22.1	20.3	20.0	17.5	17.0

Orchard 3 ‘06	August 30	September 7	September 13	September 20	September 27
M1 lbs	15.6	14.2	14.1	12.7	12.4
M2	22.3	18.6	18.8	17.7	15.8

Table 3. ‘d’Anjou’ firmness at harvest . Values are lbs. M1: highest pressure in outer portion of fruit, 0-0.32”; M2: highest pressure in fruit region 0.32” to coreline.

Protocols for 1-MCP that ensure predictable ripening

'd'Anjou' 1-MCP/CA: 'd'Anjou' pears treated with 300 ppb 1-MCP at harvest were stored in CA with 0.5% CO_2 and up to 5% O_2. After 6 and 9 months plus 7 days at 68 ^oF , peel color rating (1=green, 5=yellow) increased with O_2 concentration but 1-MCP-treated fruit remained greener than controls. Softening increased with increased O_2 concentration after 6 and 9 months, however, after 6 months, 1-MCP treated fruit did not soften to 6 lbs or less in 7 days. After 9 months, 1-MCP-treated fruit stored at 3 or 5% O_2 softened to 3.8 and 3.4 lbs, respectively. Fruit treated with 1-MCP did not develop scald regardless of storage environment, and decay incidence in some cases was lower in 1-MCP-treated fruit. This trial shows the potential for mitigation of 1-MCP-induced ripening delay over long storage durations by O_2 management during CA storage.

Month	O_2 %	Color d7		Lbs		Scald (%)		Decay (%)	
		C	MCP	C	MCP	C	MCP	C	MCP
3	1	1.7	1	3.1	13	0	0	0	0
	3	1.9	1	2.6	12.9	0	0	0	0
	5	2.2	1.2	2.7	12.7	0	0	0	0
6	1	2.6	1	1.9	12.3	0	0	6	6
	3	3.2	1.6	1.8	10.6	0	0	0	0
	5	3.6	1.7	1.6	9.5	11	0	6	6
9	1	2.4	1.4	2.0	12.4	89	0	6	6
	3	3.6	2.9	2.4	3.8	67	0	33	6
	5	4.0	3.2	2.7	3.4	67	0	44	0

Table 4. Quality of 1-MCP treated 'd'Anjou' pears after storage. Fruit treated with 300 ppb 1-MCP at harvest. Fruit held 7 days at 68 ^oF after removal from CA. C: untreated control; MCP: 300 ppb 1-MCP at harvest.

Impact of Ethylene and CO_2 on 1-MCP efficacy: 'Bartlett' pears were treated with 0 or 300 ppb 1-MCP with up to 1000 ppm ethylene or up to 4% CO_2 present during treatment. The presence of 1 or more ppm ethylene was sufficient to completely inhibit efficacy of 1-MCP (table 5). CO_2 concentrations of 2 or 4% during 1-MCP treatment reduced the magnitude of 1-MCP responses (table 6). The results indicate ethylene at relatively low amounts during 1-MCP treatment at harvest can prevent treatment effectiveness and that CO_2 present during treatment can also influence fruit response to 1-MCP.

Treatment	Ethylene	Peel color	Titratable acid %	Lbs	Scuffing %
Control	0	5	0.250	2.5	0
1-MCP	0	2.8	0.332	18.2	0
1-MCP	1	4.8	0.244	2.1	0
1-MCP	10	5	0.202	2.1	12
1-MCP	100	5	0.227	2.1	11
1-MCP	1000	5	0.193	2.0	11

Table 5. 'Bartlett' pear quality after 2 months storage in air plus 7 days at 68 ^oF. Fruit treated with 300 ppb at harvest with 0, 1, 10, 100, or 1000 ppm ethylene. Peel color: 1=green, 6=yellow.

Month	Treatment	CO_2	lbs	color 1-5	IB	decay %
2	Control	ambient	2.4	5.0	89	0
	1-MCP	ambient	17.6	2.6	0	0
	1-MCP	0.5%	17.5	2.7	0	0
	1-MCP	1.0	17.2	2.8	0	0
	1-MCP	2.0	15.2	3.6	0	6
	1-MCP	4.0	2.1	5.0	0	0
4	Control	ambient	--*	--*	--*	100
	1-MCP	ambient	13.8	5.0	0	0
	1-MCP	0.5%	13.5	4.9	0	0
	1-MCP	1.0	12.8	4.8	0	0
	1-MCP	2.0	8.3	5.0	0	11
	1-MCP	4.0	1.2	5.0	100	61

Table 6. 'Bartlett' pear quality after air storage plus 7 days at 68 ^oF. Fruit treated with 300 ppb 1-MCP at harvest with ambient, 0.5, 1.0, 2.0, or 4.0% CO_2. Peel color: 1=green, 5=yellow; IB: internal breakdown. --*: all fruit decayed.

Delayed 1-MCP treatment of Bartlett pears: Fruit were treated with 1-MCP at harvest, the day prior to removal from CA, or after removal from CA. After 2 months storage, delayed 1-MCP treatments slowed but did not prevent ripening. Treatment with 1-MCP after 4 months was not effective. Ethylene produced by fruit accumulated to 18 ppm during the 1-MCP treatment after 4 months. The results indicate the benefits in ripening delay from 1-MCP treatment decrease with increased storage duration between harvest and treatment application.

Month	Treatment	Color 1-5	lbs
2	Control	2.5	3.6
	1-MCP at harvest	1.1	18.9
	1-MCP during CA	1.7	6.1
4	Control	3.6	3.5
	1-MCP at harvest	1.8	16.5
	1-MCP during CA	3.8	3.5
	1-MCP after CA	3.7	3.4

Table 7. Bartlett fruit quality after storage. 1-MCP applied at harvest or prior to or after removal from CA. Fruit held 4 days at 68 ^oF after removal from storage.

Responses of 'Bartlett' pears to field applied 1-MCP.

An experimental formulation of 1-MCP was applied to 'Bartlett' pear trees in commercial orchards in two seasons. In 2005, two application dates (A:1 week preharvest, 19.0 lbs; B:1 day prior to commercial harvest, 17.3 lbs) and 3 rates were evaluated. Half the fruit from each field application was also treated with SmartFresh® after harvest. Evaluation of fruit after harvest indicated treatment efficacy for slower ripening as well as a possible effect of fruit maturity at the time of application. After 4 months storage in air, treatment effects from field applications on ripening were not apparent, but the efficacy of a post-storage temperature pre-conditioning period was evident for fruit receiving a postharvest application of 1-MCP.

Treatment Date	Control	M0	M1	M2	M3
A	2.3	2.2	2.4	5.4	7.0
B	4.1	3.9	4.6	14.2	14.9

Table 8. 'Bartlett' firmness after harvest. A: Harvest 1 fruit held 5 days at 50 ^oF plus 7 days at 68 ^oF, or B:Harvest 2 fruit held 7 days at 68 ^oF. Control: unsprayed; MCP: 0,1,2,3 relative amounts; M0 is oil only; P: postharvest SmartFresh® application at 300 ppb.

	Control	P	M0	M1	M2	M3
Lbs	6.8	4.7	4.7	3.6	4.1	3.7

Table 9. 'Bartlett' firmness after 4 months storage in air plus a 13 day pre-conditioning period.
Control: unsprayed; M: 1-MCP 0,1,2,3 relative amounts, M0 is oil only; P: postharvest SmartFresh application at 300 ppb.

In 2006, 2 field rates were evaluated as was the influence of harvest delay after application. 1-MCP was applied 7 days prior to the date of anticipated harvest. Fruit were harvested weekly for 4 weeks after application. A postharvest 1-MCP treatment (300 ppb) was performed at each harvest date, and fruit were stored at 31 ^oF: in air for 1 or 2 months; or CA (1.5/0.5 O_2/CO_2) for 4 months. Impacts on ripening at harvest from field treatments were detectable through 3 weeks after treatment. Fruit size increased in the first two weeks after commercial harvest. Field treatment effects on stored fruit were observed through 2 months where field 1-MCP treatments slowed ripening but fruit became acceptably soft (<6 lbs) in four days after removal from storage. Fruit harvested 2 or 3 weeks after commercial harvest did not show treatment effects after 2 months in air storage.

Harvest	Weight	1-MCP A		1-MCP 2A		spreader only		control		SmartFresh	
		day 1	day 4	day 1	day 4	day 1	day 4	day 1	day 4	day 1	day 4
Aug 28	182 g	17.2	16.8	16.8	16.7	16.6	16.3	16.6	15.3	17.1	16.3
Sep 5	217	15.2	14.4	14.8	14.5	13.9	12.0	14.5	13.7	15.0	14.7
11	243	13.6	11.0	13.1	9.6	11.8	6.7	13.8	6.8	12.3	10.3
18	243	10.8	5.0	10.6	4.7	10.0	4.9	10.1	4.0	10.4	8.1

Table 10. 'Bartlett' weight (all treatments) and firmness

Harvest	1-MCP A		1-MCP 2A		spreader only		control		SmartFresh	
	day 1	day 4	day 1	day 4	day 1	day 4	day 1	day 4	day 1	day 4
Aug 28	1.1	1.7	1.0	1.7	1.2	2.2	1.5	3.0	1.4	2.0
Sep 5	1.4	2.2	2.0	3.0	2.3	2.5	2.2	3.6	2.2	2.5
11		2.8		3.3		3.3		3.9		3.3
18	3.3	4.2	3.3	4.5	3.5	4.3	3.6	4.9	3.6	4.3

Table 11. Bartlett color 1 and 4 days after 1 month in air. A: 1-MCP 1x; 2A: 1-MCP 2x.

Harvest	1-MCP A		1-MCP 2A		spreader only		control		SmartFresh	
	day 1	day 4	day 1	day 4	day 1	day 4	day 1	day 4	day 1	day 4
Aug 28	15.7	13.4	15.6	14.1	15.9	5.6	15.2	3.4	15.3	15.5
Sep 5	14.1	8.0	13.5	6.1	11.8	4.2	13.0	3.1	14.0	13.3
11		10.2		8.5		7.7		6.2		10.2
18	7.1	2.6	8.1	2.9	7.7	2.7	5.7	2.2	7.0	6.8

Table 12. Bartlett firmness 1 and 4 days after 1 month in air. A: 1-MCP 1x; 2A: 1-MCP 2x.

Harvest	1-MCP A		1-MCP 2A		spreader only		control		SmartFresh	
	day 1	day 4	day 1	day 4	day 1	day 4	day 1	day 4	day 1	day 4
Aug 28	0	0	0	0	0	0	0	0	0	0
Sep 5	0	0	0	0	0	0	0	0	0	0
11		8		0		17		17		21
18	33	33	21	13	13	19	25	42	29	45

Table 13. Bartlett internal breakdown 1 and 4 days after 1 month in air. A: 1-MCP 1x; 2A: 1-MCP 2x.

Harvest	1-MCP A		1-MCP 2A		spreader only		control		SmartFresh	
	day 1	day 4	day 1	day 4	day 1	day 4	day 1	day 4	day 1	day 4
Aug 28	2.3	2.5	2.3	3.2	2.4	3.1	2.3	4.3	2.6	2.8
Sep 5	2.6	3.3	2.8	3.4	3.2	3.8	3.0	4.7	3.1	3.5
11	3.6	4.1	3.8	4.1	3.8	4.9	4.0	5.0	3.5	4.0
18	4.0	5.0	4.0	5.0	4.0	5.0	4.0	5.0	4.0	5.0

Table 14. Bartlett color 1 and 4 days after 2 months in air. A: 1-MCP 1x; 2A: 1-MCP 2x.

Harvest	1-MCP A		1-MCP 2A		spreader only		control		SmartFresh	
	day 1	day 4	day 1	day 4	day 1	day 4	day 1	day 4	day 1	day 4
Aug 28	15.4	11.7	14.7	10.3	15.3	3.3	14.7	2.6	15.0	15.1
Sep 5	13.9	4.9	13.1	4.3	10.1	3.5	11.6	3.3	13.7	12.8
11	10.9	3.5	10.4	3.2	8.7	3.2	9.6	3.0	10.8	9.1
18	7.9	3.5	6.7	3.0	8.1	3.8	7.3	3.5	8.6	7.2

Table 15. Bartlett firmness 1 and 4 days after 2 months in air. A: 1-MCP 1x; 2A: 1-MCP 2x. 2 months.

Harvest	1-MCP A		1-MCP 2A		spreader only		control		SmartFresh	
	day 1	day 4	day 1	day 4	day 1	day 4	day 1	day 4	day 1	day 4
Aug 28	0	0	0	0	0	0	0	0	0	0
Sep 5	0	0	0	0	8	13	0	4	0	0
11	8	4	4	4	17	25	21	25	21	0
18	46	29	50	39	50	14	46	17	42	17

Table 16. Bartlett internal breakdown 1 and 4 days after 2 months in air. A: 1-MCP 1x; 2A: 1-MCP 2x.

Responses of 'Bartlett' and 'd'Anjou' pears stored at the low O_2 limit defined by chlorophyll fluorescence: 2004: The O_2 concentration at which changes in peel chlorophyll fluorescence of 'Bartlett' and 'd'Anjou' pears (3 lots each) occurred were 0.2 and 0.3% O_2, respectively Fruit were stored in CA with 0.5% CO_2 with 1.5 (control) or 0.4 O_2 for 'Bartlett' and 0.5% O_2 for 'd'Anjou'. Responses of both cultivars varied between lots and with storage duration. 'Bartlett' fruit stored at 0.5% O_2 were slightly greener than fruit stored at 1.5% O_2 when fruit was removed from CA. Incidence of core browning, senescent scald, and internal breakdown were reduced by storage at 0.5% O_2. 'd'Anjou' fruit stored at 0.4% O_2 degreened slower, did not develop scald, and softened slower but two lots developed peel speckling compared to fruit stored at 1.5% O_2. Increasing O_2 concentration to 1.5% during storage was not consistently effective to prevent development of speckling.

Month	Trt	Color d0	TA %	Core B %	Sen. Scld %	IB %	Lbs d7	Decay %
2	air	2.7	0.314	42	0	0	2.3	2
	1.5 O_2	1.4	0.351	0	0	0	2.0	0
	0.4 O_2	1.1	0.354	0	0	0	2.0	0
4	Air	4	-	-	40	-	-	72
	1.5 O_2	2.8	0.313	0	0	37	1.4	4
	0.4 O_2	1.9	0.347	0	0	9	1.9	2
6	Air	-	-	-	94	-	-	41
	1.5 O_2	3.5	0.268	15	5	29	1.8	59
	0.4 O_2	3.0	0.301	4	0	4	2.0	44

Table 17. 'Bartlett' fruit quality after storage. Fruit were held at 68 ^oF for 7 days prior to analysis. Values are means for 3 lots. Trt: treatment; Color: 1=green, 5=yellow; Core B: core browning incidence; sen scld: senescent scald incidence; IB: internal browning and/or breakdown; decay: decay incidence.

Month	Trt	Color d0	Color d7	TA %	Scald %	lbs	Decay %
2	RA	1.5	2.6	0.248	0	1.9	0
	1.5 O_2	1.4	1.8	0.264	0	3.4	0
	0.5 O_2	1.2	1.9	0.274	0	5.8	0
4	RA	2.5	3.6	0.221	0	2.1	4
	1.5 O_2	1.2	2.3	0.247	0	1.9	2
	0.5 O_2	1.0	1.9	0.243	0	2.9	0
6	RA	3.1	3.8	0.185	39	2.6	59
	1.5 O_2	1.4	2.5	0.223	2	1.5	6
	0.5 O_2	1	2.0	0.232	0	2.4	4
8	RA	3.7	4	0.156	91	3.4	72
	1.5 O_2	1.7	2.7	0.206	12	1.8	20
	0.5 O_2	1.4	2.3	0.206	0	2.2	13

Table 18. 'd'Anjou' fruit quality after storage. Fruit were held at 68 ^oF for 7 days prior to analysis. Values are means for 3 lots. Trt: treatment; Color: 1=green, 5=yellow; TA: titratable acidity: speckling: peel speckling incidence; scald: superficial scald incidence; decay: decay incidence.

Lot	O_2/CO_2	Speckling %
A	1.5/0.5	0
	0.5/0.5	71
	0.5/0.5 2months	0
	0.5/0.5 4months	0
	0.5/0.5 6 months	61
B	1.5/0.5	0
	0.5/0.5	0
	0.5/0.5 2months	0
	0.5/0.5 4months	0
	0.5/0.5 6 months	0
C	1.5/0.5	0
	0.5/0.5	39
	0.5/0.5 2months	12
	0.5/0.5 4months	44
	0.5/0.5 6 months	61

Table 19. Incidence of 'd'Anjou' peel speckling after CA storage. Fruit were held in CA at 1.5/0.5% or 0.5/0.5% O_2/CO_2 for 8 months, or 0.5/0.5% for 2, 4, or 6 months then 1.5/0.5% to 8 months.

In 2005, ‘d‘Anjou’ pears (3 lots) obtained at commercial harvest were analyzed for changes in the chlorophyll fluorescence signal at O_2 concentrations as low as 0.1%. No change in fluorescence during the analysis of any of the lots was observed through May. The storage O_2 setpoint of 0.4% was accompanied by CO_2 concentrations of 0.5 or less than 0.1% to determine if impacts from CO_2 occur during ultra low O_2 storage. Through 8 months fruit stored at 0.4% O_2 had slower rates of softening, color change and acid loss compared to fruit stored at 1.5% O_2 (Table 20). Superficial scald developed after 6 and 8 months only on fruit stored at 1.5% O_2. No speckling was observed, and no O_2 concentration effects on decay incidence were observed. No evidence of anaerobic metabolism induced by low O_2 treatments was observed via analyses of ethanol, acetaldehyde, and methanol. After 8 months, fruit stored at 0.4% O_2 appeared to have less of these compounds compared to fruit stored at 1.5% O_2.

Months	Treatment	lbs	Color	TA%	scald	decay	EtOH*	Act*	MeOH*
2	1.5 O_2 0.5 CO_2	3.6	1.8	0.230	0 %	0 %	2.1	0	0
	1.5 O_2 0.1 CO_2	3.9	1.7	0.242	0	0	2.2	0	0
	0.4 O_2 0.5 CO_2	11.6	1.5	0.275	0	0	6.3	0	0
	0.4 O_2 0.1 CO_2	11.3	1.5	0.300	0	0	6.9	0	0
4	1.5 O_2 0.5 CO_2	2.2	1.9	0.205	0	0	21	1.2	2.5
	1.5 O_2 0.1 CO_2	1.7	2.2	0.150	0	0	17	1.0	2.3
	0.4 O_2 0.5 CO_2	4.6	1.5	0.241	0	0	33	1.4	1.6
	0.4 O_2 0.1 CO_2	7.7	1.3	0.250	0	0	28	1.3	0
6	1.5 O_2 0.5 CO_2	1.8	3.0	0.193	0	4	58	2.6	17
	1.5 O_2 0.1 CO_2	1.8	3.0	0.191	6	4	65	3.3	20
	0.4 O_2 0.5 CO_2	5.2	2.1	0.207	0	7	55	2.4	0.6
	0.4 O_2 0.1 CO_2	7.2	1.7	0.215	0	2	55	2.6	0
8	1.5 O_2 0.5 CO_2	2.0	2.7	0.202	25	15	127	7.5	53
	1.5 O_2 0.1 CO_2	2.1	2.6	0.196	33	15	161	10	57
	0.4 O_2 0.5 CO_2	5.2	2.2	0.241	0	15	102	4.8	3.7
	0.4 O_2 0.1 CO_2	6.1	2.1	0.287	0	6	90	4.5	1.8

Table 20. ‘d‘Anjou’ fruit quality after storage. Fruit were held at 68 ^{o}F for 7 days prior to analysis. Values are means for 3 lots. Color: 1=green, 5=yellow; d: days ripening after removal from storage; TA: titratable acidity; EtOH: ethanol, mg/kg; Act: acetaldehyde, mg/kg; MeOH: methanol, mg/kg.

Summary

Characterization of pear maturity at harvest relies primarily on firmness assessment. Other indices evaluated previously and as part of this study including starch hydrolysis, ethylene production, soluble solids content, titratable acidity, and color have not proven to be consistently reliable indicators of physiological development. Evaluations in this study of emission of other volatile compounds indicated detectable changes that were coincident with maturation, however, the changes detected were not consistent across lots or seasons, or occurred after optimum maturity for storage was reached. This lack of consistency relative to firmness measurements appears to limit the applicability of volatile analysis as performed as an assessment of maturity and storability.

A more extensive evaluation of fruit firmness may provide additional information that could be utilized at harvest. The standard method of firmness measurement where only the outer portion of the fruit is assessed provides only partial information regarding fruit physical condition. Softening and changes in texture are not uniform throughout pear fruit. The studies conducted for this project indicated for ‘d’Anjou’ in particular, detectable changes in fruit firmness and other properties were observed that could be useful as an indication of storability. Considering only firmness values for the outer (0.32”, M1) and inner (0.32” in to the coreline, M2) portions of the fruit, several patterns emerged. Instances were observed where firmness changes in the outer portion (M1) were not detected over a several week period were accompanied by significant changes in M2 values over the same period. Another pattern showed consistent differences between lots in M2 values when similar M1 values were measured. Lots with higher M2 values may take longer to ripen as these fruit go into storage with a higher inner as well as overall fruit firmness. The postharvest studies in this project were not sufficient to evaluate possible relationships between these values and storability, therefore, further research is needed to establish the utility of the M1/M2 relationship as an at-harvest tool.

The commercial use of SmartFresh continues to be limited by the uncertainty of ripening by treated fruit after storage. Studies conducted in this project indicated interactions between CA environment used for 1-MCP treated fruit exist that may provide a means to enhance ripening capacity. While the success of higher O_2 concentrations to promote earlier ripening of treated fruit is consistent with the long history of CA research, a challenge that remains in implementing this type of protocol is an assessment of lot to lot performance under conditions that reflect commercial reality. The CA system used in these studies provides a means to evaluate many combinations of gas composition and temperature. However, the number of fruit and lots testable under our conditions is relatively small and larger scale trials at the commercial or semi-commercial level are needed for validation.

The results of studies evaluating impacts of ethylene and CO_2 present during 1-MCP treatment show these compounds may interfere with treatment efficacy. These studies were conducted using only one rate of 1-MCP, further research is required to determine if other 1-MCP rates can reduce the risk of ethylene and/or CO_2 impacts on treatment efficacy.

Field use of 1-MCP shows potential as another means to impact fruit ripening. For 'Bartlett', a harvest delay of one week in this study resulted in a significant fruit size increase. Results from 2006 indicate the duration of a field 1-MCP application is less than a postharvest treatment, however, fruit firmness continued to decrease following field 1-MCP application. Ideally a delay in firmness loss in the field would assure fruit are packable with minimal scuffing after harvest. Development of a field protocol for 1-MCP that can result in delayed harvest with less of a postharvest response may be a means to increase harvested fruit size with less potential for marketing issues related to ripening.

Long-term storage of pears continues to provide challenges related to quality and disorder control. The potential for storage at O_2 concentrations at less than what is current industry practice was demonstrated for superficial scald control, ripening delay, and lack of accumulation of anaerobic products that could impact consumer acceptance. Storage at <1% O_2 was not without problems, specifically, development of peel speckling occurred only in the lowest O_2 environments. No incidence of pithy brown core was observed, a disorder previously identified by Paul Chen, OSU, retired, as a risk during ultra low O_2 storage of 'd'Anjou'. Speckling was a lot to lot phenomena in these studies, and lot specific factors influencing its development are currently unknown. Future research to provide insight into the physiology of speckling development may ultimately be a means to develop protocols for low O_2 d'Anjou' storage that mitigate the risk of speckling development.