FINAL PROJECT REPORT

Project Title: MCP and edible coatings to extend storage and marketing life of pears

PI:	Jinhe Bai	**Co-PI(2):**	
Organization:	Oregon State Univ.	**Organization:**	
Telephone/email:	541-386-2030 jinhe.bai@oregonstate.edu	**Telephone/email:**	
Address:	Mid-Columbia Ag. Ctr.	**Address:**	.
Address 2:	3005 Experiment Station Dr	**Address 2:**	
City:	Hood River	**City:**	
State/Zip:	Oregon 97031	**State/Zip:**	

Cooperator: Robert Spotts, Peter Sanderson, and James Mattheis

Budget History:

Item	**Year 1:**	**Year 2:**	**Year 3:**
Salaries			21,333
Benefits			12,586
Wages		14,700	
Benefits			
Equipment			
Supplies	15,000	14,700	4,500
Travel		300	500
Miscellaneous			
Total	15,000	29,700	38,919

Significant findings:

- Thermofogging of ethoxyquin substantially controlled superficial scald of Anjou pears. A dosage of 60 g per ton at harvest plus a second fogging at 30 g per ton after two months of storage gave the best control.
- MCP completely controlled superficial scald of Anjou pears. However, it caused a loss of ripening ability. Study of re-initiating the ripening ability is on-going.
- Field applications of MCP decreased scald incidence of Anjou pears.
- MCP (300 ppb) treatment + pre-conditioning after storage extended storage life of Bartlett pears for two months in both RA and CA storage.
- A coating made of soybean oil emulsion reduced the incidence of superficial scald on Anjou pears.
- A candelilla coating increased the shelf-life of Concorde pears for one week.

Results and Discussion

1. Effect of MCP on scald incidence and ripening ability of Anjou pears

1) High dose + pre-conditioning (Fig. 1)

Background and objective: Commercially applicable doses of MCP (300 ppb) controlled scald of Anjou pears, but the fruit lost its ripening ability. Therefore, we adopted a pre-conditioning period to re-initiate ripening.

Methods:

- 1-MCP: 300 ppb at 70°F for 24 hours
- Pre-conditioning: at 50-70°C for 5-20 days

Report:

- Superficial scald: Completely controlled scald after 6 mths in RA or 9 mths in CA
- Ripening ability: did not reach eating quality regardless of temperature and time of pre-conditioning (6 lb, Fig. 1).

2) Short treatment + pre-conditioning (Fig. 2)

Objective: To improve ripening ability by delaying harvest, and decreasing MCP treatment time and temperature.

Methods:

- Harvest maturity: commercial, one- and two-week(s) delayed
- MCP: 300 ppb at 33°F for 6 hours
- Pre-conditioning: at 50°F for 5-15 days

Results:

- Superficial scald: unacceptable incidence after 6 mths in RA or 9 mths CA (Fig. 2A)
- Ripening ability: Most of the treatments did not reach eating quality, except when harvested two-weeks delayed + stored for 6 mths in RA or 9 mths in CA + pre-conditioning at 50°F for 15 + shipping at 33°F for 2-3 weeks (FF ≤ 6 lb, Fig. 2B).
- Sensitivity of pears to 1-MCP is higher in one-week delayed fruit, but lower in two-weeks delayed one.

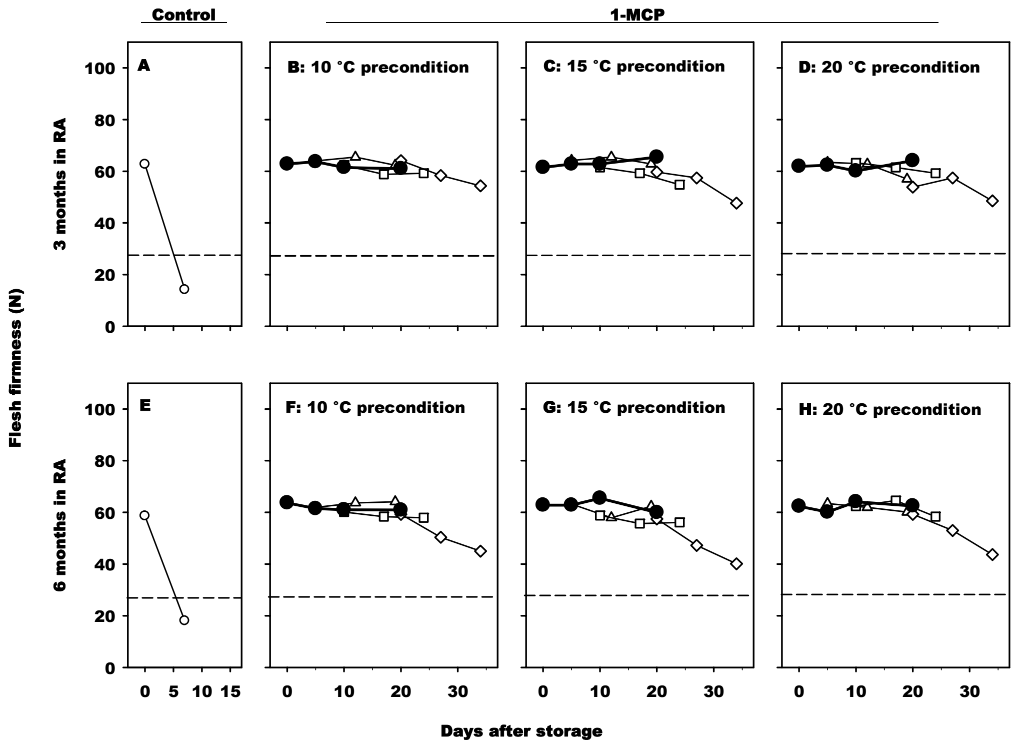

Fig. 1. The effect of MCP treatment on softening of Anjou pears. Fruit were treated with 300 ppb MCP at harvest and stored at 30F for up to 6 months before preconditioning.

3) Low dose + pre-conditioning (Table 1)

Objective: To improve the ripening by decreasing MCP dose to 50 ppb

Methods:

- MCP: 50 ppb at 33°F for 24 hours
- Pre-conditioning: at 50°F for 5-15 days

Results:

- Superficial scald: ~0 after 4 mths in RA or 6 mths in CA (Table 1) and unacceptable incidence after 6 mths in RA or 8 mths in CA.
- Ripening ability: With 5 days of pre-conditioning, fruit softened to eating quality (6 lb, Table 1)

4) Low dose of MCP + delayed ethoxyquin combination (Fig. 3)

Background and objective: 25 ppb of MCP reduced scald without inhibiting ripening. For full control of scald, a delayed ethoxyquin treatment was applied within 60 days of storage. Ethoxyquin is labeled to be used within 7 d after harvest, but for practical purposes it is difficult to perform the application within such a narrow window.

Methods:

- 1-MCP: 25 ppb at 70°C for 24 hours.
- Ethoxyquin: after 1, 7, 30 or 60 days of cold storage, 1000 ppm ethoxyquin

Results:

- Superficial scald: controlled for up to 5 mths in RA.
- Ripening ability: ripened normally.

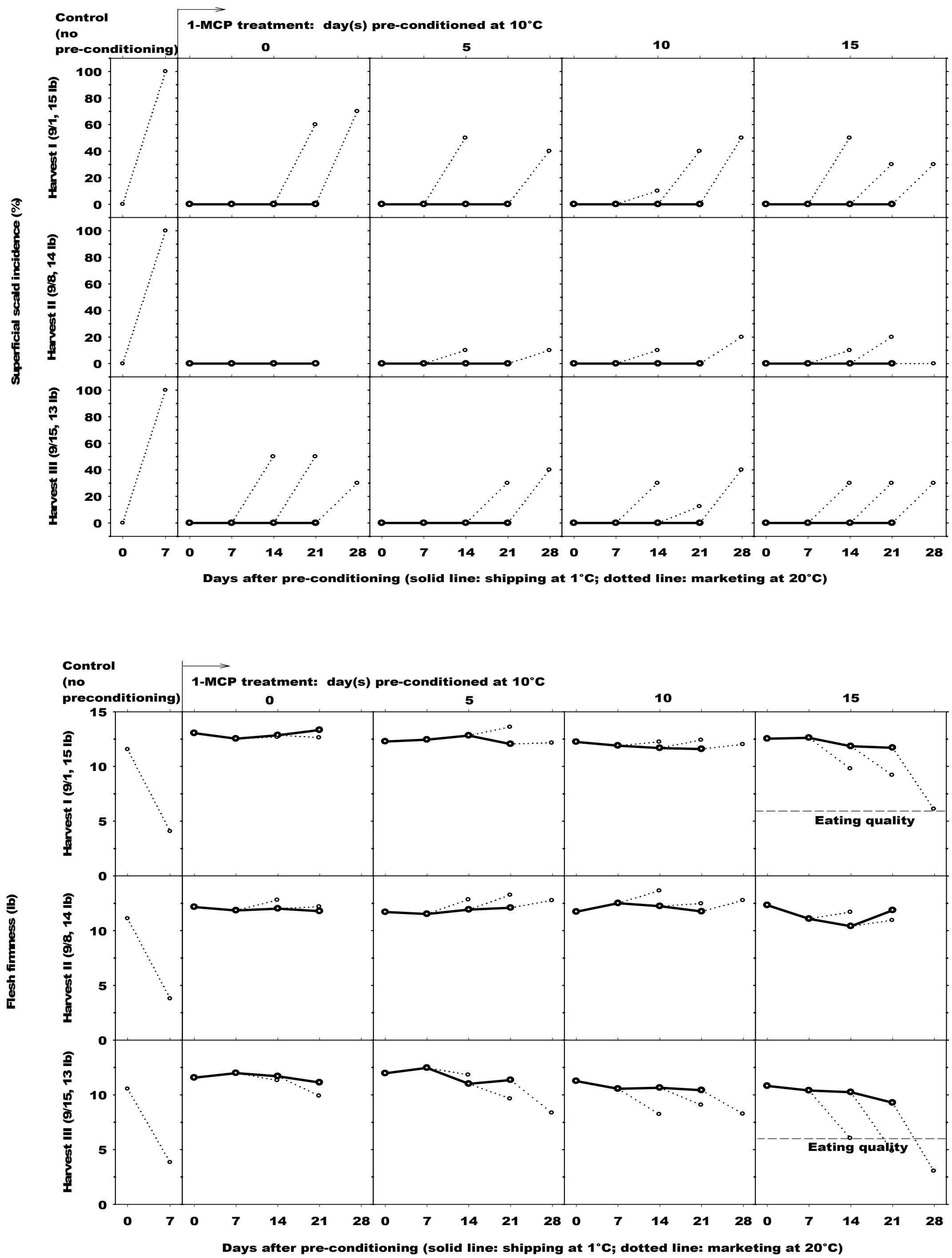

Fig. 2. Effect of MCP treatment on superficial scald incidence (upper, A) and flesh firmness (bottom, B) of Anjou pears. Fruit were harvested at commercial harvest maturity, or one or two week(s) delayed. MCP treatment was applied immediately after each harvest. Fruit were stored at 30F for 6 months before preconditioning.

Table 2. Effects of harvest maturity and postharvest 1-MCP application on ripening behavior and superficial scald of Anjou pears. Fruit were harvested at commercial maturity or 10 days delayed respectively. 1-MCP (55 ppb) was applied at harvest and after 2, 4 and/or 6 months of air or CA storage. Preconditioning was applied for 1-MCP treated fruit for 5 days at 50°F prior to ripening (no preconditioning for the control fruit) for 7 d at 68°F..

Harvest	1-MCP application time (months)	Air				1-MCP application time (months)	CA			
		FF (lb)		Scald			FF (lb)		Scald	
		Before ripening	After ripening	Incidence (%)	Index [z]		Before ripening	After ripening	Incidence (%)	Index
		4 months					***6 months***			
Commercial harvest	Control	14.3	3.1	56.7	1.6	Control	13.8	3.4	26.7	1.0
	0	15.1	2.7	10.0	0.6	0	14.8	4.6	2.5	0.1
	0+2	15.2	2.7	13.3	0.7	0+4	14.6	2.9	0.0	0.1
delayed harvest	Control	13.0	3.6	60.2	1.8	Control	13.3	4.3	30.0	1.0
	0	14.6	4.8	3.3	0.3	0	13.6	6.1	0.0	0.1
	0+2	13.3	4.9	10.0	0.5	0+4	13.6	6.6	0.0	0.2
F-value and significance										
	Harvest (H)	15.52**	8.11*	0.96	0.33	Harvest (H)	6.4	7.83*	0.03	0.07
	MCP (M)	4.21*	0.65	25.92***	15.86***	MCP (M)	1.3	2.04	7.16*	12.39**
	H x M	1.12	1.26	0.19	0.55	H x M	0.3	1.47	0.06	0.04
		6 months					***8 months***			
Commercial harvest	Control	12.6	3.6	68.3	2.3	Control	12.7	3.8	8.3	0.2
	0	13.2	3.3	22.4	0.8	0	14.5	2.8	22.6	0.8
	0+2	13.3	2.7	20.0	1.1	0+4	13.7	2.1	24.9	0.9
	0+4	13.8	2.5	26.7	1.0	0+6	13.6	2.1	28.8	1.0
	0+2+4	13.3	3.0	43.3	1.4	0+4+6	13.9	2.9	10.4	0.6
delayed harvest	Control	12.1	4.3	83.3	2.7	Control	12.2	3.0	15.3	0.5
	0	12.8	3.3	30.0	1.1	0	13.4	4.4	0.0	0.0
	0+2	12.7	3.6	36.7	1.2	0+4	14.1	3.3	3.3	0.3
	0+4	12.7	2.7	23.0	1.0	0+6	14.0	4.3	0.0	0.0
	0+2+4	13.1	4.9	31.8	1.0	0+4+6	14.0	3.4	6.1	0.2
F-value and significance										
	Harvest (H)	1.97	6.91*	0.00	0.07	Harvest (H)	0.27	8.27*	11.42**	11.53**
	MCP (M)	1.32	4.13*	4.14*	3.88*	MCP (M)	4.01*	0.76	0.26	0.51
	H x M	0.22	1.55	0.29	0.22	H x M	1.14	3.04	2.49	2.22

1. Ripening behavior: A 5-day preconditioning was needed for 1-MCP treated fruit. (Fruit did not soften to 6 lb without preconditioning)
2. Scald control: 1-MCP application at harvest significantly controlled scald for at least 6 months in both air and CA storage.
3. Delayed harvest did not decrease scald incidence, nor did multi-applications of 1-MCP.
3. Unexpected results: After CA storage for 8 months, scald incidence decreased except the treatment harvested at commercial maturity and treated with MCP.

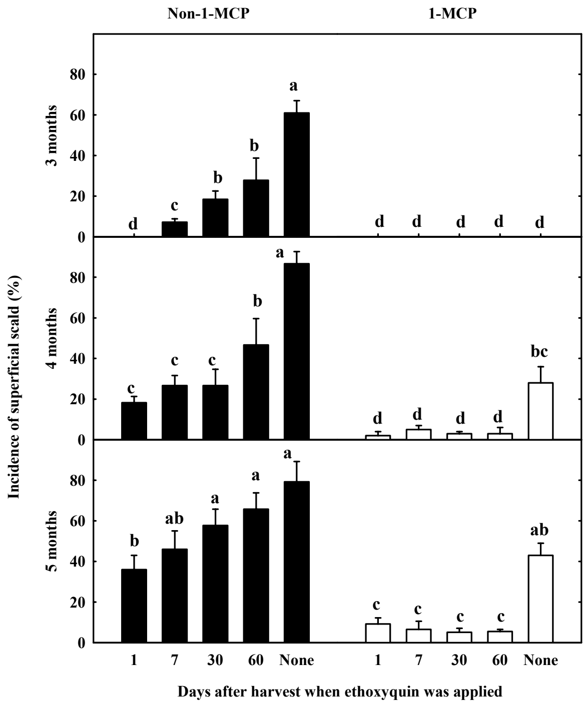

Fig.3. The effect of MCP and ethoxyquin on superficial scald incidence of Anjou pears. Fruit were treated (solid) or untreated (open) with 25 ppb MCP for 24 hours immediately after harvest and then stored at 33°F for up to 5 months. Ethoxyquin drench (1000 ppm) was applied after 1, 7, 30 or 60 days of cold storage. Superficial scald was evaluated after 3, 4, or 5 month storage at 33°F followed by 7 days of shelf life at 70°F. Vertical lines represent SD (n = 3). Within the same storage time (sampling day), vertical bars labeled with the same letter are not significantly different at P = 0.05 using Duncan's multiple range test.

2. Effect of MCP on senescent disorders and ripening ability of Bartlett pears (Table 2)

Background and objective: Storage life of Bartlett pears is relatively short in comparison with winter pears. After 2 months of RA storage or 4 months of CA storage, senescent scald and/or senescent breakdown occur and cause an end of the storage life. The objective of this research was to extend storage and the marketing life of Bartlett pears without a "permanent" loss of the ripening ability.

Methods:

- MCP: 300 ppb at 70°F for 24 hours
- Pre-conditioning: at 50-70°C for 5-20 days

Results:

- Storage life: MCP treated fruit had two months longer storage life in comparison with non-MCP control in both RA and CA storages at 30F.
- Marketing life: MCP treated fruit had one week longer marketing life in comparison with non-MCP control at 70F.
- Ripening ability: The ripening ability of MCP-treated 'Bartlett' fruit recovered in response to many pre-conditioning combinations of 50°-70°C for 10-20 days, as indicated by a decrease in flesh firmness to 6 lb or lower.

3. Thermofogging of ethoxyquin to control Anjou scald (Table 3)

Objectives: To improve efficiency of ethoxyquin application and decrease chemical burn (phytotoxicity) caused by drenching.

Methods:

- Dose: 60 – 90 g/T for the primary fogging at harvest and 30-60 g/T for the second fogging after 2 months of storage.

Results:

- Best treatment based on 2-year results: an initial treatment with 60 g/T dose plus a second fogging of 30 g/T controlled superficial scald as well as drenching at 1000 ppm with less pytotoxicity.

Table 2. Flesh firmness and incidence of internal breakdown of 'Bartlett' pears during shelf life at 20°C

Treatment	Preconditioning		Flesh firmness (N)			Internal breakdown (%)		
	Temperature (°C)	Days	Day-0	Day-7	Day-14	Day-0	Day-7	Day-14
			2 month stored in RA					
Control	0	0	76	7	ND [1]	0	0	57
1-MCP	10	5	83	71	30	0	0	0
		10	81	51	15	0	0	0
		20	77	16	7	0	0	0
	15	5	83	57	18	0	0	0
		10	72	34	14	0	0	0
		20	32	10	ND	0	0	77
	20	5	80	58	13	0	0	0
		10	64	23	11	0	0	0
		20	15	ND	ND	0	73	100
	LSD $_{0.05}$		4	5	2	0	3	2
			4 month stored in RA					
Control	0	0	73	ND	ND	0	97	100
1-MCP	10	5	78	50	21	0	0	0
		10	70	33	ND	0	0	50
		20	32	ND	ND	0	33	67
	15	5	76	38	17	0	0	0
		10	65	24	ND	0	0	63
		20	18	ND	ND	0	77	100
	20	5	76	34	ND	0	0	37
		10	56	19	ND	0	0	63
		20	ND	ND	ND	77	93	100
	LSD $_{0.05}$		6	3	2	2	6	4
			4 month stored in CA					
Control	0	0	79	8	ND	0	0	33
1-MCP	10	5	83	74	31	0	0	0
		10	81	59	24	0	0	0
		20	78	20	9	0	0	0
	15	5	79	72	25	0	0	0
		10	78	47	17	0	0	0
		20	33	10	ND	0	0	53
	20	5	77	68	20	0	0	0
		10	69	25	12	0	0	0
		20	13	ND	ND	0	70	100
	LSD $_{0.05}$		4	6	3	0	3	3
			6 month stored in CA					
Control	0	0	69	ND	ND	0	47	100
1-MCP	10	5	77	54	26	0	0	0
		10	71	35	ND	0	0	63
		20	52	ND	ND	0	57	100
	15	5	74	53	15	0	0	0
		10	69	28	ND	0	0	63
		20	21	ND	ND	0	37	67
	20	5	77	40	ND	0	0	47
		10	58	19	ND	0	0	77
		20	ND	ND	ND	37	67	100
	LSD $_{0.05}$		5	1	1	3	5	6

Table 3. Thermofogging of Xedaquin A (ethoxyquin) and Pyrimethanil control superficial scald and decay of Anjou pears

No.	Method of application	Initial ethoxyquin dose (9/20)	2nd fog ethoxyquin dose (12/1)	Pyrimethanil dose (9/20)	Pyrimethanil residue (11/30)	Ethoxyquin residue (12/1)	Scald: Incidence (%)	Scald: Index (4: severe; 3: moderate; 2: slight; 1: very slight; 0: clear)	Phytotoxicity: Incidence (%)	Phytotoxicity: Index (4: severe; 3: moderate; 2: slight; 1: very slight; 0: clear)	Decay (%)
1	Fog (g/T)	0	0	90	1.3		76.8 ab[z]	2.6 b	6.9 d-f	0.2 e-h	0.5 bc
2	Fog (g/T)	0	30	90	4.7	n.d.	64.3 bc	1.9 c	4.4 d-f	0.3 e-h	2.8 bc
3	Fog (g/T)	0	60	90	0.7	2.2	52.3 c	1.7 c	12.3 b-f	0.4 c-f	1.1 bc
4	Fog (g/T)	60	0	60	1.3		16.8 de	0.7 de	2.0 ef	0.1 gh	0.5 bc
5	Fog (g/T)	60	30	60	3.6	2.3	11.4 e	0.5 de	1.6 f	0.1 h	1.3 bc
6	Fog (g/T)	60	60	60	1.3	n.d.	11.8 e	0.5 e	9.6 c-f	0.4 d-g	4.3 b
7	Fog (g/T)	90	0	60	0.7		18.4 de	0.7 de	1.4 f	0.1 gh	0.0 c
8	Fog (g/T)	90	30	60	2.6	2.7	11.6 e	0.5 de	5.9 d-f	0.3 e-h	0.3 bc
9	Fog (g/T)	90	60	60	2.2	4.3	12.3 e	0.6 de	6.6 d-f	0.3 e-h	1.8 bc
10	Drench (ppm)	1000	0	90	7.8		4.3 e	0.3 e	13.0 b-e	0.6 b-d	1.3 bc
11	Drench (ppm)	1000	30	90	3.3	n.d.	6.4 e	0.5 de	14.7 b-d	0.6 b-d	1.9 bc
12	Drench (ppm)	1000	60	60	2.5	2.8	3.3 e	0.4 e	12.7 b-f	0.5 c-e	1.5 bc
13	Drench (ppm)	1500	0	60	2.4		4.0 e	0.4 e	19.3 a-c	0.7 a-c	1.9 bc
14	Drench (ppm)	1500	30	60	4.1	2.5	2.5 e	0.4 e	21.5 ab	0.7 ab	2.2 bc
15	Drench (ppm)	1500	60	60	8.0	2.7	7.4 e	0.4 e	28.6 a	0.9 a	2.1 bc
16	Fog (g/T)	0	0	0	n.d.		84.9 a	3.1 a	2.5 ef	0.1 gh	9.9 a
17	Fog (g/T)	60	0	0	n.d.		29.7 d	1.0 d	1.5 f	0.1 gh	1.9 bc
18	Fog (g/T)	90	0	0	0.3		13.4 e	0.6 de	1.7 f	0.2 f-h	1.5 bc
19	Drench (ppm)	1000	0	0	n.d.		12.4 e	0.7 de	1.7 f	0.2 f-h	3.7 bc
20	Drench (ppm)	1500	0	0	n.d.		7.4 e	0.4 e	4.5 d-f	0.3 e-h	2.0 bc

[z] Mean values (n=6) not followed by the same letter are significantly different (P<0.05) by Duncan's multiple range test.

4. **Pear coating development**

1) Soybean oil emulsion coating alleviated superficial scald of Anjou pears (Table 4)

Methods: A soybean oil emulsion coating was developed for pears. The major components were soybean oil (The Hain Food Group, Inc., Uniondale, NY), polyoxyethylenesorbitan monostearate and sorbitan monostearate. Soybean oil coatings were diluted to total solids of 5%, and coated onto Anjou pears with gloved hands. Carnauba and carnauba + shellac mixture coatings (both diluted to a total solids of 5%), along with a non-coating control were applied as a comparison. After 4 months of RA storage, coated or non-coated fruit were held at 68°F for up to 2 weeks.

Results: The gas concentration inside the fruit for the various coatings ranged from 6-12 % CO_2 and 14-6 % O_2. Superficial scald was observed in the control fruit with 100% incidence and a scald index of 1.0. Carnauba and carnauba + shellac mixtures decreased the scald index to 0.5-0.7. However, soybean emulsion significantly decreased scald index to 0.28. This coating alleviated the severities of scald but did not exterminate scald. There was no difference between the coating treatments based on scald incidence.

Generally, coating decreases scald by reducing oxygen diffusion from the atmosphere to inside the fruit, slowing oxidations of phenolic compounds, and the aging metabolism of fruit. However, soybean oil adds another function to coating – antioxidant power. Soybean oil contains rich unsaturated acyloxies and other functional molecular structures which capture free radicals and protect fruit from disorders.

Table 4. Effect of soybean oil emulsion and other coatings on internal CO_2 and O_2, weight loss, superficial scald and flesh firmness of Anoju pears. Fruit stored at 30°F for 4 months were transferred to 68°F for 16 hours before applying coatings. Coated and non-coated fruit were then held at 68°F for 14 days.

Coating	Internal gas (%)		Weight	Superficial scald		Flesh firmness
	CO_2	O_2	loss (%)	Incidence (%)	Index	(lb)
			Day 7 at 68°F			
Non-coated	1.4 c[z]	19.3 a	4.1 a	100 a	1.0 a	2.4 c
Carnauba 5%	8.1 b	11.8 bc	1.4 c	96 a	0.52 b	4.1 b
Carnauba + shellac 5%	10.6 a	8.9 c	1.9 b	94 a	0.46 b	4.9 a
Soybean oil	7.1 b	13.4 b	1.6 bc	89 a	0.21 c	4.4 ab
			Day 14 at 68°F			
Non-coated	2.6 c	17.5 a	5.7 a	100 a	1.0 a	1.3 b
Carnauba 5%	7.6 b	12.6 b	2.0 c	100 a	0.63 b	2.7 a
Carnauba + shellac 5%	9.5 a	10.2 c	2.7 b	100 a	0.69 b	2.9 a
Soybean oil	10.1 a	9.8 c	2.6 b	100 a	0.28 c	2.5 a

[z] Means (n = 10) were separated with DMRT (P = 0.05). Means followed by a common letter are not significantly different.

2) Edible coatings for pears (Table 5 and 6)

Background and objectives: The application of coatings to pears prior to marketing is becoming a standard practice. 'Delicious' apple has been a key commodity in the development of fruit coating formulations and technology, and because this cultivar is relatively tolerant to high gas barriers, the coatings developed have tended to emphasize improvement of visual gloss with little need for other effects on the fruit that might result from a high barrier to gas exchange. A shellac coating seems an excellent fit for dark red 'Delicious' apples because it imparts high gloss, hides bruises and forms a modified atmosphere condition that tends to preserve firmness and prolong shelf-life in this variety.

It is well known that when fruit is separated by a barrier, such as a coating or packaging, from exchange of gases with the atmosphere there is the possibility for the respiration to become anaerobic which is associated with the development of off-flavors. Therefore, coatings and packaging developed for one type of fruit may not be suitable for another.

Pears are sensitive to high levels internal CO_2 levels and have different color in comparison with red apples. They may also differ from apples in the porosity of the peel and the structure of blossom- and stem- ends, and thus the same coating may result in a different modified internal atmosphere, and physiological reactions to a given internal gas composition may also differ. The pear industry usually uses 10 times diluted apple waxes for their pear coating to avoid CO_2 injury. However, there is no research indicating proper pear coating and proper air barrier for pears. These considerations suggest it appropriate to once again determine how to select coatings for pears. There also seems a possibility that the trend in consumer preference for more 'natural' products might lead to less preference for high glossy coatings for pears.

Methods: We selected three coating formulations: shellac, carnauba and candellila, and up to four concentrations of each formulation. One of the intermediate coating formulations was made mostly of candelilla wax, which is considered a GRAS substance, which is allowed by the FDA with no limitations other than good manufacturing practice (CFR, 184.1976). Apples with candelilla wax coatings have a nearly natural, non-coated appearance (preliminary experiments). Other coatings are carnauba wax microemulsion (intermediate gas permeability) and shellac solution (low gas permeability), both materials being commonly used in fruit coatings. These coatings were used with 2-4 months stored pears of 'Anjou', 'Concorde' and 'Bartlett'. The coated or non-coated fruit were held at 68 °F for up to 2 weeks to simulate the marketing conditions.

Results: The gas concentration inside the fruits for the various coatings ranged from 1-18 % CO_2 and 16-2 %O_2 (Table 5). The coatings with intermediate gas permeability (5-10% carnauba and candelilla) gave intermediate values of CO_2 and O_2 in the internal fruit. The coatings with lowest permeability (carnauba 20%) caused high internal CO_2, low O_2, resulting in anaerobic fermentation in pears. Candelilla coated pears showed lowest gloss and provided a more natural appearance (Table 6).

Table 5. Internal CO_2 and O_2 (%) of pears at 68°F for 7 days after application of different coatings.

Carnauba concentration (%)	d'Anjou		Bartlett		Concorde	
	CO_2	O_2	CO_2	O_2	CO_2	O_2
0	2	19	3	18	2	16
2	3	15	4	13	4	12
5	7	11	8	10	10	9
10	13	6	15	3	12	7
20	16	2	20	1	17	2

Table 6. Gloss, weight loss, and firmness of 'd'Anjou' pears coated with different formulations after 7 days at 68 °F

Coating	Gloss (GU)	Weight loss (%)	Firmness (N)
Non-coated	5.8	3.6	11
Candelilla 5%	6.9	2.1	22
Candelilla 10%	7.5	1.7	25
Carnauba 5%	9.7	1.8	19
Carnauba 10%	10.9	1.4	27
Shellac 5%	11.1	2.5	26
Shellac 10%	13.4	2.2	33