USE OF DIPHENYLAMINE, ETHOXYQUIN AND SEMPERFRESH ON ANJOU PEARS

Eugene Kupferman and Jake Gutzwiler
WSU—TFREC
1100 North Western Ave.
Wenatchee WA 98801
Kupfer@wsu.edu

ABSTRACT

This paper summarizes five years of research on chemical treatments to control storage scald of Anjou pears. Chemicals used include the antioxidants diphenylamine (DPA) and ethoxyquin, as well as a sucrose ester marketed as Semperfresh. Applications included different combinations, concentrations and formulations. Both antioxidants controlled storage scald when used at label rates; however, chemical marking developed when fruit was in contact with other fruit or against container walls. In general ethoxyquin was more effective than DPA in controlling storage scald, but ethoxyquin-treated fruit developed more internal browning than untreated fruit or fruit drenched with DPA. Chemical marking was reduced when antioxidant concentration was reduced, or fruit was not in contact with other fruit. Semperfresh in combination with antioxidant improved scald control. Pears treated with antioxidant and/or Semperfresh were greener than untreated fruit. Firmness was higher in Semperfresh treated Anjou pears, but it was not affected by antioxidant. Additional research is required, but it appears that either DPA or ethoxyquin can be used to control storage scald of Anjou pears.

INTRODUCTION

Producers of Anjou pears are faced with the challenge of storing fruit for a marketing season that may last up to 10 months and then providing wholesale customers with pears in various types of boxes and in various configurations. These may include plastic or carton boxes and the pears may or may not be wrapped in tissue paper.

The traditional method of handling Anjou pears in the Wenatchee Valley is to cool pears to below 35 ºF, sort and pack fruit for the longest term storage hand-wrapped in treated paper (containing copper, ethoxyquin and oil) and pack into cartons. The cartons are palletized by size and grade and placed into controlled atmosphere (CA) storage.

During the shipping season an increasing number of wholesale buyers request that the pears be unwrapped and shipped in either plastic or fiber ‘eurotrays’ in cartons or returnable plastic containers (RPCs). This requires that the fruit be further handled at a time when they are most susceptible to scuffing injury.

A superior option would be to store pears in bins and pack them into the requested container, thus eliminating double handling. However, Anjou pears stored in bins are susceptible to storage scald and fungal decay. Apples are also susceptible to these risks and are stored in bins for up to 11 months but only after the bins are drenched with an antioxidant such as diphenylamine (DPA) and a fungicide. Commercial experience with drenching Anjou pears has led operators to determine that the risk of chemical fruit marking and fungal decay is too high to employ this technique.

This study was initiated to determine the risk of chemical marking on pears from two types of antioxidants, ethoxyquin and DPA, when used in a drenching situation. The standard pear antioxidant is ethoxyquin and the standard apple antioxidant is DPA. It is possible that DPA may reduce the risk of chemical marking in pears while still controlling scald. Another reason to explore the use of DPA on pears is because the pear industry is the only horticultural user of ethoxyquin and continued registration of this product for use as an antioxidant scald deterrent is not guaranteed. Semperfresh, a sucrose ester used on other commodities to retard ripening, was also evaluated in these studies in combination with the antioxidants.

METHODOLOGY

Anjou pears harvested over five seasons were drenched in different combinations of antioxidant (DPA and ethoxyquin) and Semperfresh solutions (Table 1). DPA was applied as either "NoScald DPA 283" (formerly Elf Atochem now Cerexagri, Inc.) or "Shield Liquid DPA 15 or 31%' (Pace International). Ethoxyquin was applied as "Deccoquin 305 Concentrate" (Cerexagri, Inc.). "Semperfresh" is manufactured by AgriCoat, UK. Pears were stored in various packing containers and held in CA conditions for 6 to 8 months. Analysis of fruit after storage was conducted to determine the effect of the drench solutions in reducing scald and skin marking. Analysis included measurement of hue angle (skin color), scald, chemical marking, firmness, soluble solids (SS), acidity and internal browning. Although each experiment was different, the primary goal was to determine the usefulness of antioxidant and Semperfresh drenches on long-term stored Anjou pears.

Table 1. 1997 to 2001 Anjou pear antioxidant experiments.

Year	Drench type	Fruit origin	Packing	Storage	Treatments	Analysis
1997	Hand	At harvest from orchard	Commercial packing	Commercial CA @ 30.5 ºF 1.8% O_2, 0.8% CO_2 8 months	Paper wrap, Semperfresh, ethoxyquin	Hue angle, scald, chemical marking, shrivel, weight, decay, firmness, internal browning, SS and acidity
1998	Hand		Commercial packing	7 months RA for ethoxyquin and DPA and 8 months commercial CA for Semperfresh combinations	ethoxyquin and DPA and combinations of Semperfresh with DPA and ethoxyquin	Hue angle, scald, firmness, internal browning
1999	Hand		Packed in lab	6 weeks RA, then 6 months commercial CA	Combinations of Semperfresh with DPA and ethoxyquin	Hue angle, scald, chemical marking, shrivel, decay, internal browning
2000	Hand	Packing-house	Loose in plastic lug	Commercial CA @ 31.5 ºF 1.5% O_2, 1.0% CO_2 8 months	Combinations of Semperfresh with DPA and ethoxyquin	DPA residue, hue angle, scald, chemical marking, firmness, internal browning
2001	Commercial	Direct from orchard	Loose in plastic cherry bin	Commercial CA @ 31.5 ºF 1.5% O_2, 1.0% CO_2 8 months	Combinations of Semperfresh with DPA and ethoxyquin	Hue angle, scald, chemical marking, firmness, internal browning

1997 METHODS

Semperfresh Study

Pears were harvested from five commercial growers representing a range of temperature zones. Drenching took place in a lab-model, hand-driven drencher to compare the effect of water, Semperfresh, and Semperfresh with ethoxyquin on post-storage quality. Thiabendazole (TBZ) was included in Semperfresh, ethoxyquin and water drench solutions to control decay, and an additional solution of Semperfresh without TBZ was used in the experiment.

Paper Wrap Study

Fruit were commercially wrapped in plain paper, copper-treated paper, or "super copper" (copper and ethoxyquin treated) paper, or were unwrapped and packed into carton boxes that were retained in CA storage for 8 months.

In both experiments pears were held at room temperature for 1 day after storage and 20 pears were evaluated for hue angle (skin color), shrivel, firmness, internal browning, soluble solids and acidity. Twenty pears from each treatment were also held for 7 days after storage at 70 ºF for the same evaluation with the addition of scald.

1997 RESULTS

Semperfresh Study

Pears drenched with Semperfresh were firmer than those drenched in water (Table 2). An ethoxyquin drench with Semperfresh resulted in the firmest pears after 7 days. Pears drenched in Semperfresh had a higher hue angle (more green color) than those treated with water alone. Fruit treated with both ethoxyquin and Semperfresh had the highest hue angle (most green color) after 7 days. The drench of Semperfresh alone was ineffective as a scald deterrent but ethoxyquin with Semperfresh controlled scald. Treatments containing Semperfresh resulted in at least 16% of pears developing internal browning. Ethoxyquin treated pears developed more internal browning than pears drenched with Semperfresh or water.

Semperfresh alone had no effect on shrivel; although the Semperfresh with ethoxyquin resulted in increased shrivel.

Table 2. Effect of Semperfresh and ethoxyquin on Anjou pear quality, 1997.

	Firmness (lbf)		Hue angle		Scald	IB	Shrivel
Drench treatment	OFS+1	OFS+7	OFS+1	OFS+7	(%)	(%)	(%)
Control	12.5 c	3.1 c	116.7 b	112.2 c	29 a	1 c	4 b
Semperfresh	13.0 a	3.9 b	117.6 ab	114.9 b	21 b	16 b	4 b
Semper+ethoxyquin	12.7 b	4.5 a	117.8 a	115.3 a	4 c	35 a	9 a

OFS+1 = Out of storage + 1 day
OFS+7 = Out of storage + 7 days
Scald, internal browning and shrivel were all evaluated at OFS+7 days

Paper Wrap Study

Fruit stored without paper wrap were firmer after 7 days than wrapped fruit (Table 3). Scald was higher in unwrapped fruit or fruit wrapped in plain paper. Internal browning was higher in unwrapped fruit. Even plain paper showed more control of internal browning than unwrapped fruit.

Table 3. Effect of type of paper wrap on Anjou pear quality, 1997.

Drench treatment	Firmness (lbf)		Hue angle		Scald (%)	IB (%)	Shrivel (%)
	OFS+1	OFS+7	OFS+1	OFS+7			
No paper	12.6 B	4.3 a	117.5	114.1 b	27 a	28 a	5 ab
Plain paper	12.6 B	3.8 b	117.9	114.6 a	23 a	16 b	8 a
Copper paper	12.9 A	3.5 c	117.0	114.6 a	14 b	14 bc	5 ab
Super copper paper	12.9 A	3.5 c	117.3	113.7 c	8 b	10 c	4 b
OFS+1 = Out of storage + 1 day OFS+7 = Out of storage + 7 days Scald, internal browning and shrivel were all evaluated at OFS+7 days							

Drenching with ethoxyquin or applying an antioxidant as a paper wrap are equally effective in reducing scald. When ethoxyquin was present, either in paper (super copper paper) or as a drench, scald was suppressed (Tables 2 and 3). Because results indicated drenches are as effective as wrapping fruit in paper, experiments in subsequent years were expanded to exploring methods for successfully storing scald-free pears loose in bins, rather than in packed boxes.

1998 METHODS

Pears were collected from three commercial growers and drenched with equipment used in 1997. Two drench solution studies were carried out in 1998.

Antioxidant Study

Drench solution materials used were Shield 15% DPA and NoScald 283 DPA at 1000 and 2000 ppm, ethoxyquin at 2700 ppm, or water control. All solutions contained a thiabendazole fungicide (Merck TBZ) to reduce decay. After commercial packing in paper wrappers (copper and super copper), cartons of pears were stored in a regular storage cold room at 32 ºF for 7 months.

Semperfresh Study

Drench solution treatments included a water control, Semperfresh, ethoxyquin at 2700 ppm, Shield 15% DPA at 2000 ppm, and combinations in which Semperfresh was used with each antioxidant. Pears were wrapped in copper or super copper paper and stored for 8 months in a CA room.

In both studies, 10-pear samples were evaluated for hue angle (skin color), firmness and internal disorders one day after being removed from storage. Seven days out of storage at 70 ºF, 30 pears were evaluated for scald and internal browning. Semperfresh treated fruit were evaluated for internal browning, soluble solids and acidity.

1998 RESULTS

Antioxidant Study

The effect of antioxidant on firmness immediately out of storage was small and hue angle (skin color) was not affected (Table 4). Scald was suppressed by the ethoxyquin drench to a greater extent than with DPA, but internal browning occurrence in the ethoxyquin treatment was higher than with other treatments.

Table 4. Effect of antioxidants on Anjou quality, 1998.

Treatment	OFS+1		OFS+7	
	Firmness (lbf)	Hue angle	Scald (%)	IB (%)
Water	9.4 ab	106.3	91 a	1 b
NoScald DPA, 1000 ppm	9.2 ab	110.6	81 ab	3 b
NoScald DPA, 2000 ppm	9.6 a	111.1	72 b	4 b
Shield DPA, 1000 ppm	9.1 b	111.2	78 b	1 b
Shield DPA, 2000 ppm	9.3 ab	110.8	71 b	1 b
ethoxyquin, 2700 ppm	8.9 b	109.3	37 c	11 a
OFS+1 = Out of storage + 1 day OFS+7 = Out of storage + 7 days				

Semperfresh Study

Fruit treated with Semperfresh in combination with DPA or ethoxyquin were firmer and had less scald than control or fruit treated with either chemical alone (Table 5). Scald was most effectively suppressed on fruit drenched with Semperfresh with either DPA or ethoxyquin added. In fruit not treated with Semperfresh, scald occurred less often in fruit drenched with ethoxyquin than with DPA. Internal browning was not affected by treatment.

There was no effect of paper type or an interaction between paper and drench this year (data not shown).

Table 5. Effect of Semperfresh on Anjou pear quality, 1998.

Treatment	Firmness (lbf)		OFS+7	
	OFS+1	OFS+7	Scald (%)	IB (%)
Water	11.1 c	2.1 c	62 a	3
Semperfresh	11.6 bc	2.1 c	57 a	6
Semperfresh+ethoxyquin	12.5 a	2.7 b	3 c	1
Semperfresh+DPA	12.1 ab	3.1 a	8 c	3
Ethoxyquin	10.9 c	2.0 cd	10 c	2
DPA	11.8 ab	2.0 d	33 b	0
OFS+1 = Out of storage + 1 day OFS+7 = Out of storage + 7 days				

1999 METHODS

Antioxidant Studies

Commercially grown Anjou pears were harvested and stored in air at 40 ºF. After six weeks the pears were drenched in the lab-model, hand-driven drencher for two minutes with Shield 15% or NoScald 283 DPA at 2000 ppm or ethoxyquin at 2700 ppm. Fruit were then wrapped in copper treated paper and placed on trays in apples boxes and stored in commercial pear CA storage for six months, before transfer to ambient temperature. Five days out of storage, the pears were evaluated for hue angle (skin color), scald, chemical marking, firmness, soluble solids, acidity and internal browning.

After drenching, a sub-sample of fruit was placed into plastic lugs without wrappers to determine the potential for chemical marking. This sub-sample of fruit was stored in the same rooms with the packed boxes of pears.

Semperfresh Study

The procedure was the same as the Antioxidant Studies (above). Fruit were treated with either NoScald 283 or Shield 15% DPA at 2000 ppm or ethoxyquin at 2700 ppm with and without Semperfresh.

Fruit were evaluated one day out of storage. Quality evaluations on 66 pears per treatment packed in copper paper included examination of hue angle (skin color), scald, firmness, soluble solids, acidity, and internal browning. Fruit stored loose in plastic lugs were evaluated for shrivel, decay and chemical burn.

Pear Temperature Study

At harvest, bins of Anjou pears were purchased from a commercial packinghouse and drenched in the lab-model, hand-driven drencher for two minutes. Shield 15% DPA and NoScald 283 DPA were applied at 2000 ppm and ethoxyquin was applied at 2700 ppm. Each drench was applied to pears at "warm" (70 ºF) and "cold" (50 ºF) flesh temperatures. Each treatment was either rinsed after drenching or left unrinsed. After all treatments were applied, samples of pears were sent to analytical laboratories for DPA residue analysis.

Pears were evaluated for hue angle (skin color), firmness, soluble solids, and acidity one day out of storage. Seven days out of storage pears were evaluated for hue angle (skin color), scald, chemical marking, firmness and internal browning.

1999 RESULTS

Antioxidant Studies

Fruit treated with any of the antioxidants were firmer than the control (Table 6). Antioxidant treated fruit had a higher hue angle (more green skin color). Chemical marking was equally severe among antioxidant treatments and worse than the control. Shrivel and internal browning were not present at a level that was significant when fruit were stored in apple boxes. Antioxidant treated pears stored in plastic lugs had significantly more chemical marking than control fruit (Table 6).

Table 6. Quality of antioxidant-treated pears, 1999.

Treatment	Firmness (lbf)		Hue angle		Scald (%)	Chemical marking (%)	DPA residue (ppm)
	OFS+1	OFS+5	OFS+1	OFS+5			
Control	10.8 b	3.4 b	110.4 b	107.5 c	8 a	3 b	N/A
Ethoxyquin	11.4 a	3.9 a	111.0 a	108.2 b	0 b	19 a	N/A
NoScald DPA	11.3 a	3.9 a	111.1 a	108.8 a	1 b	18 a	4.8
Shield DPA	11.1 a	4.0 a	111.3 a	109.0 a	2 b	15 a	3.4

OFS+1 = Out of storage + 1 day
OFS+5 = Out of storage + 5 days
Scald and chemical marking were evaluated at OFS+5 days

Semperfresh Study

Firmness of Semperfresh treated pears, whether treated with an antioxidant or not, was higher than without Semperfresh (Table 7). Semperfresh treated pears had a higher hue angle (more green color) non-treated fruit. Semperfresh treated fruit had less internal browning. There was more decay but less shrivel in Semperfresh treated fruit. There was less chemical marking on Semperfresh treated fruit.

Pear Temperature Study

Firmness, color and scald after storage were not affected by the temperature of the pears at the time of drenching. Whether or not the pears were rinsed following drenching with an antioxidant also did not affect these results (data not shown).

Fruit that was not rinsed had appreciably more chemical marking than fruit that was rinsed (Table 8). Chemical marking occurred almost exclusively on fruit that was in contact with the sides or bottom of the plastic lugs.

Table 7. Quality of Semperfresh and antioxidant-treated Anjou pears, 1999.

Treatment	Firmness (lbf) OFS+5	Hue angle	Decay (%)	IB (%)	Shrivel (%)	Chemical marking (%)
Control	2.9 d	102.1 ef	73 a	65 a	0 c	40 bcd
Semperfresh	4.1 ab	105.3 bc	N/A	40 bc	N/A	N/A
NoScald 2000 ppm	3.7 bc	103.3 d	10 cd	48 ab	3 c	77 a
NoScald 2000 ppm + S	4.5 a	106.7 a	30 bc	46 b	2 c	49 bc
Shield 2000 ppm	3.6 bc	103.6 d	24 cd	54 ab	10 bc	56 b
Shield 2000 ppm + S	3.5 c	106.0 ab	34 bc	23 c	5 c	37 cd
Ethoxyquin 2700 ppm	3.3 cd	102.8 c	4 e	58 ab	18 ab	51 bc
Ethoxyquin 2700 ppm + S	3.8 cd	104.7 de	7 de	51 ab	26 a	28 d

OFS+5 = Out of storage + 5 days
S = Semperfresh

Table 8. Chemical marking in rinsed and unrinsed pears, 1999.

Rinse Treatment	Contact w/plastic lug	Chemical marking (%)
Unrinsed	Contact	40 a
	No contact	2 b
Rinsed	Contact	2 b
	No contact	0 b

DPA residue was affected by both rinsing and pear temperature (Table 9). DPA residue was higher when fruit were not rinsed. DPA residue was highest when fruit were not rinsed and were warm (70 ºF) when treated. When fruit were rinsed, temperature did not affect residue level.

Table 9. DPA residue on unrinsed and rinsed warm and cold pears, 1999.

DPA formulation	Rinse?	Pear temperature	DPA residue (ppm)
NoScald	Unrinsed	Warm (70 ºF)	8.9 a
		Cold (50 ºF)	5.5 bc
	Rinsed	Warm (70 ºF)	1.8 d
		Cold (50 ºF)	3.0 cd
Shield	Unrinsed	Warm (70 ºF)	6.5 ab
		Cold (50 ºF)	3.2 cd
	Rinsed	Warm (70 ºF)	1.6 d
		Cold (50 ºF)	2.3 d

2000 METHODS

Antioxidant Study

Commercially acceptable Anjou pears were selected from three orchard-run bins and randomized into plastic lugs. A minimum of 44 pears were placed into each plastic lug to optimize fruit-to-fruit contact. Fruit were drenched for 1 minute in various concentrations and formulations of antioxidants under the hand-driven lab-model drencher. DPA formulations included Shield 15%, Shield 31% (not available in the United States), and NoScald 283 (31%, formulated by Cerexagri, Inc.). Drench solutions included each DPA formulation at concentrations of 500, 1000 and 2000 ppm and ethoxyquin at concentrations of 1000 or 2700 ppm. Drench solutions were repeated with Semperfresh at every concentration of antioxidant. There was also a fresh water control and a Semperfresh and water control. All treatments had TBZ included in the drenching solution. Each treatment was replicated three times. The temperature of the fruit and drenching solution was 67 ºF. After drenching, the plastic lugs were covered with perforated plastic liners and stored in CA at 1.5% O_2, <1.0% CO_2 at 31.5 ºF.

Soon after drenching, six pears of each treatment were sampled for DPA residue.

Pears were removed from CA storage and examined after 7 months in commercial CA storage. Each pear in the lug was examined for chemical marking, scald, decay and internal browning. Ten fruit per lug were evaluated one day out of storage for hue angle (skin color), firmness, soluble solids and acidity. After 5 days at 68 ºF, an additional 10 fruit per lug were examined for hue angle (skin color) and firmness.

2000 RESULTS

Antioxidant Study

Analysis showed that pears drenched with DPA absorbed between 2 and 3 ppm DPA. There was no DPA residue on untreated pears.

Firmness tested one-day out of storage was unaffected by antioxidant type (Table 10). Shield DPA treated fruit were slightly less firm than control or other treatments after ripening five days. Chemical marking was lower in the control and Shield 15% than in other treatments (Table 10). Chemical marking increased as antioxidant concentration increased (Table 11). Examples of chemical marking are shown in Figure 1.

In fruit treated with DPA, firmness decreased as DPA concentration increased (Table 11). In fruit treated with ethoxyquin, the opposite was true (2700 ppm treated fruit were firmer than 1000 ppm treated fruit).

Table 10. Effect of antioxidant formulation on Anjou quality, 2000.

Formulation	Firmness (lbf)		Chemical marking (%)
	OFS+1	OFS+5	
Control	12.2	4.8 a	4 b
Shield 15%	12.1	4.2 b	4 b
Shield 31%	11.7	4.1 b	14 a
NoScald 283	12.0	4.7 a	16 a
Ethoxyquin	12.0	4.6 a	19 a
OFS+1 = Out of storage + 1 day OFS+5 = Out of storage + 5 days			

Table 11. Effect of antioxidant concentration on Anjou quality, 2000.

Concentration	Firmness (lbf)		Chemical marking (%)
	OFS+1	OFS+5	
Control	12.2 a	4.8 ab	4 c
DPA 500 ppm	12.2 a	4.5 bc	5 bc
DPA 1000 ppm	12.0 ab	4.4 cd	10 b
DPA 2000 ppm	11.5 b	3.7 e	30 a
Ethoxyquin 1000 ppm	11.6 b	4.2 d	5 bc
Ethoxyquin 2700 ppm	12.3 a	5.1 a	34 a
OFS+1 = Out of storage + 1 day OFS+5 = Out of storage + 5 days			

Semperfresh Study

Semperfresh treated fruit were firmer both out of storage and after ripening (Table 12). The application of Semperfresh did not affect chemical marking, but did result in fruit with a higher hue angle (more green color) (Table 12).

Table 12. Effect of Semperfresh on Anjou pear quality, 2000.

Treatment	Firmness (lbf)		Hue angle	Chemical marking (%)
	OFS+1	OFS+5		
Semperfresh	12.8 a	5.7 a	111.5 a	6 a
No Semperfresh	11.7 b	4.0 b	110.5 b	2 a
OFS+1 = Out of storage + 1 day OFS+5 = Out of storage + 5 days				

Figure 1a. Chemical marking on Anjou pear treated with 1000 ppm ethoxyquin after 7 months in commercial CA storage.

Figure 1b. Chemical marking on Anjou pear treated with 2700 ppm ethoxyquin after 7 months in commercial CA storage.

2001 METHODS

Antioxidant Study

Eight bins of pears from the same orchard were randomized and distributed into plastic cherry bins for drenching using a commercial drencher. Each bin was drenched for 90 seconds in drench solutions containing DPA at 500, 1000 and 2000 ppm, ethoxyquin applied at 1000 and 2700 ppm, and in combination with Semperfresh. Prior to use, the drenching solution was tested with a DPA test kit provided by Pace International. Samples were taken for DPA residue analysis after the bins had drained. Pears were stored for 7 months of CA storage at 1.5% O_2, 1.0% CO_2 and 33 ºF.

All pears were evaluated for chemical marking on the first day out of storage. Twenty pears from each treatment were evaluated for hue angle (skin color), scald, firmness and internal browning after 1, 3, 6, 8, 10, and 12 days at 70 ºF.

2001 RESULTS

Antioxidant Study

Scald did not develop on a sufficient number of fruit to determine the effectiveness of antioxidants against this disorder. Firmness increased slightly as concentration of antioxidant increased (Table 13). Hue angle (skin color) was not affected by antioxidant. Ethoxyquin treated fruit had higher internal browning than other treatments at day 1. Chemical marking increased as antioxidant concentration increased. Examples of chemical marking are shown in Figure 2.

Table 13. Effect of antioxidant on Anjou pear quality, 2001.

Day	Antioxidant drench	Concentration (ppm)	Firmness (lbf)	Hue angle	IB (%)	Chemical marking (%)
Day 1	DPA	500	14.0 bc	112.6 bc	2 b	2 d
	DPA	1000	13.9 c	112.3 c	3 b	9 c
	DPA	2000	14.8 a	113.0 b	0 b	34 a
	ethoxyquin	1000	13.9 c	112.8 b	0 b	2 d
	ethoxyquin	2700	14.5 ab	113.0 b	13 a	22 b
	Water	0	14.0 bc	113.6 a	2 b	1 d
Day 3	DPA	500	5.4 bc	111.1 b	2	
	DPA	1000	5.0 c	111.4 b	3	
	DPA	2000	5.9 ab	112.1 a	3	
	ethoxyquin	1000	6.0 ab	111.5 b	0	
	ethoxyquin	2700	5.7 bc	111.4 b	5	
	Water	0	6.6 a	112.3 a	2	
Day 6	DPA	500	2.1 cd	109.4 ab	2	
	DPA	1000	2.0 d	109.0 bc	0	
	DPA	2000	2.7 a	109.8 a	3	
	ethoxyquin	1000	2.4 c	109.5 ab	2	
	ethoxyquin	2700	2.0 d	108.8 c	0	
	Water	0	2.4 ab	109.1 bc	2	

Figure 2. Chemical marking on Anjou pear treated with 2000 ppm DPA after 7 months in commercial CA storage.

Semperfresh Study

Semperfresh treated fruit were firmer, had a higher hue angle (more green color) and had more internal browning than untreated fruit (Table 14). Examples of internal browning seen in the Semperfresh-treated fruit are shown in Figure 3. Semperfresh treated fruit had less chemical marking.

Table 14. Effect of Semperfresh on Anjou pear quality, 2001.

Day	Treatment	Firmness (lbf)	Hue angle	IB (%)	Chemical marking (%)
Day 1	Semperfresh	15	113.7	7	< 1
	No Semperfresh	14	113.6	2	1.0
Day 3	Semperfresh	9.1 a	113.2 a	22 a	
	No Semperfresh	6.6 b	112.3 b	2 b	
Day 6	Semperfresh	4.0 a	111.6 a	10 a	
	No Semperfresh	2.4 b	109.1 b	2 b	

Figure 3. Internal browning on Anjou pear treated with 500 ppm DPA + Semperfresh after 7 months in commercial CA storage and 5 days out of storage.

CONCLUSION AND DISCUSSION

SCALD

Antioxidant

The primary use of an antioxidant is to suppress scald in long-term storage and secondarily to reduce the incidence of internal browning. In only three of the five years was scald a significant problem in untreated fruit after storage. In all three seasons (1997 to 1999) scald was controlled well by ethoxyquin drenches. In the 1998 and 1999 seasons, scald was moderately controlled by DPA as well; DPA was not used in the 1997 experiment.

Semperfresh

Semperfresh applied alone did not control scald.

Antioxidant/Semperfresh Combination

Ethoxyquin controlled scald when used in combination with Semperfresh better than ethoxyquin alone in 1998, but not in 1997. Scald was better controlled with a combination of DPA and Semperfresh than if DPA were applied alone.

COLOR

Antioxidant

In most experiments, antioxidant treated pears had a higher hue angle (more green color) after five days out of storage than control fruit, although no consistent differences were observed on concentration or type of antioxidant.

Semperfresh

In 1997, 1999 and 2001 pears drenched in Semperfresh had a higher hue angle (more green color) than control pears. Hue angle (skin color) in 1998 and 2000 was similar between Semperfresh and non-Semperfresh treatments.

Antioxidant/Semperfresh Combination

In 1997, the combination of Semperfresh and ethoxyquin had a higher hue angle (more green color) after five days than Semperfresh treatments. In 1999 DPA with Semperfresh resulted in greener fruit than other Semperfresh or antioxidant drenches. Differences in hue angle among antioxidant and Semperfresh combinations were not apparent in other years. Although there was no consistent effect of Semperfresh and antioxidant combinations on hue angle, negative results did not occur (treated fruit were not more yellow).

CHEMICAL MARKING

Antioxidant

Chemical marking was measured only in the final three years of experiments. In 1999 notes were taken on the location of pears in the plastic lug with chemical marking. Almost all fruit sustaining chemical marking in this experiment were not rinsed before being placed in storage and were in direct contact with floors or walls of the lug. This would suggest that DPA residue trapped on the bottom of storage containers caused most of the chemical marking. In the following years it was determined that increased DPA concentrations corresponded with an increase in burn incidence. Additionally, Shield 15% DPA solution elicited burn in at least 10% fewer pears than in pears treated with other antioxidants.

Semperfresh
There was no effect of Semperfresh on chemical burn.

Antioxidant/Semperfresh Combination
Results were not consistent.

FIRMNESS

Antioxidant
Application of antioxidant drenches did not affect firmness consistently, although higher firmness values corresponded with 2000 ppm DPA or 2700 ppm ethoxyquin drenches in some years.

Semperfresh
In all cases applications of Semperfresh improved firmness of pears out of storage.

Antioxidant/Semperfresh Combination
Drenches containing both compounds typically resulted in firmness values higher than the Semperfresh alone.

INTERNAL BROWNING

Antioxidant
All years in which internal browning was detected the incidence of internal browning was greater in pears treated with ethoxyquin than with DPA or control. DPA had no appreciable effect on internal browning.

Semperfresh
Pears drenched in Semperfresh in 1997 and 2001 were more likely to have internal browning than control pears. In 1998 there was no difference between Semperfresh and control fruit, and in 1999 fruit drenched in Semperfresh had less internal browning than control fruit. Although the results imply a possible potential for suppression of internal browning with Semperfresh, the effectiveness is inconsistent.

Antioxidant/Semperfresh Combination
The combination of Semperfresh with DPA is inconsistent. The combination of Semperfresh with ethoxyquin treatment resulted in more internal browning than other treatments.

SUMMARY

A comparison of trends and results described in each study summarizes the effects of drenches (Table 15).

In summary, we found that scald was not an annual problem, but ethoxyquin treatment at 2700 ppm suppressed scald better than DPA applied at 2000 or 1000 ppm. There was no major benefit to include Semperfresh to control scald. Semperfresh did result in higher hue angles (more green color retention) and higher firmness when applied with the antioxidant.

Chemical marking increased with increasing concentrations of antioxidant and was reduced when Semperfresh was included. Ethoxyquin treated fruit had more chemical marking than those treated with DPA. Rinsing fruit following application reduced chemical marking but also reduced DPA residue. Pears in direct contact with the walls and floor of the plastic lugs sustained far more chemical marking damage than other fruit.

Table 15. 1997 to 2001 comparison of trends and results.

Year	Scald	Color	Chemical marking	Firmness	Internal browning
1997	ethoxyquin and Semperfresh controlled scald Semperfresh alone did not control scald	Semper+ethoxyquin: highest hue angle (more green color)	Not measured	Firmness higher with Semperfresh and the Semper+ethoxyquin combination resulted in even higher firmness	Semperfresh increased IB. Semper+ethoxyquin further increased IB incidence
1998	ethoxyquin: good scald control DPA: moderate Semper+DPA and Semper+ethoxyquin: very good	No significant differences in hue angle	Not measured	Semper+DPA and Semper+ethoxyquin highest firmness at OFS+5 days	Low incidence of IB. Highest incidence with ethoxyquin
1999	Scald control very good with all antioxidant treatments	Control fruit had lowest hue angle (most yellow color). Semperfresh treated fruit had higher hue angle (retained more green color)	Most marking occurred in unrinsed fruit in contact with plastic lug.	Fruit with antioxidant firmer than control. Fruit with Semperfresh generally firmer.	High incidence of IB. Moderate control of IB with addition of Semperfresh
2000	No scald problem	Hue angle slightly higher (more green color) in Semperfresh treated fruit	Marking differences between antioxidant formulations. More marking with increased concentration Semperfresh no effect on chemical marking	Control fruit and ethoxyquin 2700 ppm treated fruit had highest firmness at OFS+5 days. Semperfresh treated fruit had higher firmness at OFS+1 and OFS+5 days.	No internal browning
2001	Low incidence of scald	Semperfresh treated fruit had slightly higher hue angle (more green color) after 3 and 6 days.	More marking at highest concentrations of antioxidant. Semperfresh no effect on chemical marking.	No difference in firmness on day 1. Control fruit generally firmer than antioxidant after 3 and 6 days. Semperfresh treated fruit much firmer after 3 and 6 days.	Low incidence of internal browning.

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