Postharvest Decay Control of Apples and Pears After Immersion Dumping

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Appendices

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Methods of handling harvested apples and pears changed dramatically between 1955 and 1965 with immersion dumping in packinghouses replacing the picking lug and dry dumping.

In immersion dumping, bins of fruit are carried into a tank on a chain or track. As the bin submerges, the fruit floats out and onto a packing machine. The empty bins are stacked to one side as they come out of the tank.

Dumping apples in water works well because their specific gravity is much less than 1.00 (22). Although the specific gravity of pears generally is close to 1.00, they do not float as desired in water. Early experiences of packers showed it was necessary to add salts to the dump tank water to help pears float.

Generally, sodium carbonate (soda ash), sodium sulfate, and sodium silicate are added to dump tank water until the pears float. In the dump tank, dirt and debris from the orchard accumulate. So do spores of numerous fungus species which may cause apples and pears to decay.

Our studies in 1975 to 1978 showed that dump tank water samples collected in packinghouses commonly contained spores of *Penicillium expansum* Lk. ex. Thom and *Mucor piriformis* Fischer (Appendix 2). Decay resulting from fruit passing through water contaminated with fungus spores has been reported in packinghouses since 1907 (18).**

The incidence of blue-mold rot in apples has been shown to be related to the spore load in water the apples pass through (4, 5, 9, 10). Our studies also have shown a relationship between the amount of postharvest decay in pears and the spore concentration of *M. piriformis* in solutions in which the fruit was submerged (Appendix 3).

As immersion dumping became popular, chlorine or sodium o-phenylphenate (SOPP) was added to the dump tank to help control postharvest decay. These products were the major chemical means of control of postharvest decay in apples and pears until the benzimidazole fungicides, benomyl and TBZ, were developed in the early 1970s. Because of the success of these fungicides, the use of chlorine and SOPP was dropped by many packing houses.

By 1975, it was apparent that benomyl and TBZ would not control all types of postharvest decay. Benomyl resistance was found in the blue mold organism (*Penicillium expansum)* in Oregon and Washington (3, 17) and in the gray mold organism (*Botrytis cinerea* Pers. ex. Fr.) in Oregon (3). Such diseases as Mucor rot, *M. piriformis*, initially reported as *M. globosus* (1, 6), and side rot, *Phialophora malorum* (Kidd and Beaum; McColloch), have caused extensive losses (1, 2, 6). These organisms are not sensitive to benomyl.

So, packing house operators are again looking at SOPP and chlorine for postharvest decay control (12, 15, 16, 21). This work is intended to answer some of the questions about their use.

SOPP, Chlorine Decay Control

In our tests, both materials gave some decay control. When chlorine or SOPP was mixed with a fungus spore suspension before passing fruit through the mixture, chlorine consistently gave better decay control than SOPP (Appendix 4a-c). This is comparable to controlling decay by reducing the effective spore concentration in a suspension such as in a dump tank.

In other experiments, the fruit was inoculated before treatment with chlorine or SOPP (Appendix 2d-e). Some control was achieved with SOPP. No control was achieved with chlorine. This would be comparable to controlling decay by killing spores lodged within wounds or injuries on the fruit. Fruit injuries, often minor, can become contaminated at harvest and at all handling stages thereafter. Similar results have been reported on oranges (7, 20). Results of other studies on the effectiveness of SOPP and chlorine in controlling decay of fruit and vegetables have been summarized (7, 8, 19).

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** Numbers in parentheses refer to References, page ____

Fruit Injury or Discoloration Danger

We did not observe fruit injury with chlorine alone or in combination with soda ash, sodium sulfate, or sodium silicate except where fruit remained unrinsed for several weeks. Occasionally, some surface injury was found when SOPP was used. It usually occurred when fruit was exposed to SOPP in combination with either sodium sulfate or soda ash. Exposure to SOPP alone for two hours resulted in injury in some tests. Exposure of Anjou pears to SOPP alone for one hour or either sodium sulfate or soda ash alone for two hours did not cause injury.

Fruit exposed to combined SOPP and sodium silicate was safe for at least two hours in all tests. The incidence and severity of injury to Anjou pears exposed to SOPP combined with either sodium sulfate or soda ash tended to increase as the exposure time, solution temperature, and/or salt concentration increased (Appendix 5). Initial fruit temperature did not appear to affect the result when SOPP was combined in 4 percent sodium sulfate (Appendix 5).

In general, a 15-minute exposure was safe if the solution temperature was less than 55 degrees Fahrenheit. At temperatures less than 45 degrees Fahrenheit, 30-minute exposures were safe.

When SOPP is combined with sodium sulfate or soda ash, dump tank temperatures should not exceed 55 degrees Fahrenheit. Exposures should not exceed 30 minutes, with 15 minutes being a safer maximum exposure. The minimum amount of sodium sulfate or soda ash that gives adequate pear flotation should be used.

All our data are from tests done on Anjou pears. Similar tests on Bosc pears indicated they might be slightly more resistant to injury than Anjou.

There were no differences in various brands of SOPP.

Our data should be used only as a guide since they are based on tests on 1977 season Anjou pears from Hood River, Oregon, and Wenatchee, Washington. Fruit from other seasons may react differently.

Injury was observed on Yellow Newtown apples during the 1977-1978 season. The harvested fruit had not been exposed to the dump tank. The skin in the injured area was a deep brown which some times extended into the outer flesh of the apple.

The injury nearly always was associated with fruit which had contact with bin walls. To duplicate this injury, we soaked plywood strips in SOPP, SOPP plus 6 percent sodium sulfate, or 6 percent sodium sulfate for two weeks. The strips were then removed from the solutions and dried for two weeks. Yellow Newtown apples were packed with the strips in polyethylene-lined boxes so they were tightly pressed against the treated wood.

The fruit was stored for 60 days at 30 degrees Fahrenheit and 10 days at 70 degrees Fahrenheit. The fruit in contact with the wood strips soaked in SOPP plus sodium sulfate showed severe injury. Fruit in contact with strips soaked in either SOPP or sodium sulfate alone showed no injury.

The injury was identical to that observed in bins. When using SOPP in combination with sodium sulfate, some device should be arranged to thoroughly rinse the bins as they come up out of the dump water.

Effect of Floatation Salts on Fungicidal Activity

Adding floatation salts to solutions of SOPP or chlorine can cause marked pH changes. The pH of these solutions can have an effect on their fungicidal activity (7). The pH values of various solutions are given in Appendix 6. The pH of SOPP diluted to the rate used in dump tanks varies between 11.5 and 11.9.

As the pH of these solutions is lowered, an increase in both fungicidal and phytotoxic properties will be observed (7). This may explain our observations that SOPP combined with sodium sulfate (pH = 9.7 – 10.8) was much more phytotoxic than SOPP alone or in combination with sodium silicate (pH = 11.2 – 11.9). Some fungicidal action should be available at the higher pH values (11.2 – 11.9) found when SOPP is used in water or sodium silicate.

Chlorine solutions used in packing fruit generally are prepared from calcium hypochlorite or sodium hypochlorite. The pH of these solutions has a marked effect on their rate of fungicidal action and stability in solution (7, 20). Solutions that are more stable but have slower fungicidal action produce higher pH. Laboratory tests indicated a decrease in fungicidal activity of chlorine when combined with sodium silicate (pH = 11.2) compared to solutions of chlorine in sodium sulfate (pH = 7.5 – 7.8) (Appendix 7). However, these more active chlorine solutions are less stable (8, 20). Chlorine solutions prepared in sodium sulfate have a more rapid fungicidal action but are less stable, thus requiring more frequent addition of chlorine than those prepared in sodium silicate.

Summary

Chlorine (Calcium Hypochlorite or Sodium Hypochlorite)

Advantages

1. Low cost. Any extra equipment maintenance resulting from chlorine usage would be an additional cost.
2. Provides fastest killing of spores suspended in the dump tank solution.
3. Chlorine is very effective in the pH range of 7.5 - 8.5. Chlorine (sodium hypochlorite) combined with sodium sulfate falls in this range.

Disadvantages

1. Corrodes metal, which includes most packing equipment. Chlorine may shorten bin life by corroding nails or metal straps. Constant users of chlorine argue that the corrosion is unsightly but does not cause extensive damage if maintenance is proper.
2. When sodium silicate is used as a floatation agent, the rate of fungicidal action of chlorine is reduced, probably because of the high pH of the sodium silicate.
3. Workers may find the odor of the chlorinated dump tank harsh and unpleasant if ventilation is poor.
4. Chlorine gradually breaks down and becomes inactive in the presence of organic material so generally will not penetrate small wounds to kill spores lodged there.
5. The pH ranges that offer chlorine its best fungicidal activity make it most unstable in solution.

Sodium O-Phenylphenate (SOPP)

Advantages

1. SOPP is effective and relatively safe in the pH range 11 - 12. SOPP in water or in combination with sodium silicate falls in this range.
2. It does not corrode metal.
3. It is stable in contact with organic matter and generally does a good job in penetrating wounds to kill spores lodged there.
4. It is used as an integral part of the decay control program in the citrus industry.

Disadvantages

1. SOPP is more expensive than chlorine.
2. It does not give the rapid kill of spores suspended in the dump water that chlorine does.
3. SOPP, unless used properly, has more risk of fruit injury, particularly when combined with sodium sulfate or soda ash, than chlorine.
4. Fruit put in unrinsed bins recently immersed or still wet with SOPP may develop problems. Look for injury on the side of fruit in direct contact with bin walls.

Both chlorine and SOPP, when properly used, reduce the spore load in dump tanks and help control postharvest decay. Both require monitoring to insure that proper concentration is maintained in the dump tank.

Both are caustic to skin. Employes responsible for adding and mixing the solutions or handling bins wet with SOPP or chlorine solutions should wear rubber spray gloves. Concentrated chlorine or SOPP spilled on skin should be rinsed off immediately.

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Appendices

APPENDIX 1

Specific Gravity of Pears and Aqueous Solutions of the Floatation Salts Used for Pears

Appendix 1a

Specific Gravity of Pears

METHODS

The specific gravity of four lots of pears harvested at proper maturity was determined from a 20-fruit sample of each lot. Individual pears were tied to a string at one end of a two-pan platform balance and weighed while suspended in air and in water. The specific gravity was determined from these weights.

RESULTS

Test Lot	Specific Gravity
Hood River Anjou	0.977
Wenatchee Anjou	0.991
Hood River Bosc	1.002
Medford Bosc	1.010

Appendix 1b

Specific Gravity of Aqueous Solutions of the Floatation Salts Used for Pears

METHODS

Solutions ranging from 1 percent to 7 percent concentration were prepared for sodium sulfate, sodium carbonate (soda ash), and sodium silicate. Specific gravity determinations were made using a hydrometer calibrated to read specific gravity = 1.000 in distilled water.

RESULTS

	Specific Gravity		
Concentration (%)	Sodium sulfate	Soda ash	Sodium silicate
1	1.010	1.010	1.010
2	1.015	1.020	1.010
3	1.025	1.030	1.015
4	1.035	1.035	1.020
5	1.045	1.040	1.025
6	1.055	1.050	1.030
7	1.060	1.055	1.035

APPENDIX 2

Incidence of *Mucor Piriformis* and *Penicillium Expansum* in Packinghouse Dump Tanks

METHODS

Water samples were taken from packinghouse dump tanks by submerging uncapped 100 millileter bottles to a depth of 1 to 2 inches. The water was returned to the laboratory and 0.1 millileter aliquots were spread evenly on acidified potato dextrose agar. Two or three agar plates were used for each sample. The plates were incubated in the lab at 68 to 77 degrees Fahrenheit. Colonies were counted after two to five days. Each distinct colony was taken to represent a single viable spore.

RESULTS

	Frequency of recovery in this range[a]	
No. spores/ml	*M. piriformis*	*P. expansum*
<1	66	45
1 - 9	16	9
10 - 99	39	63
100 - 999	23	26
>1000	0	1

[a] 144 samples were assayed.

APPENDIX 3

Decay of Pears in Relation to Concentration of Spores in a Solution

METHODS

Spore suspensions of *M. piriformis* were prepared to contain 10^0 to 10^7 spores per milliliter. In one experiment, Anjou pears, each with two fresh 3 millimeter x 3 millimeter punctures, were inoculated by submerging them in a basket, 10 at a time, for 30 seconds in one of the spore suspensions. Fifty pears were inoculated with each solution. After treatment, the pears were packed in polyethylene-lined boxes and placed in storage at 30 degrees Fahrenheit for 30 days. A second experiment, using Bosc pears, was done the same way.

RESULTS

Conc. (#/ml) of spores in the inoculating solution	% Infected punctures	
	Anjou	Bosc
10,000,000	100	100
1,000,000	99	99
100,000	98	98
10,000	89	88
1,000	80	86
100	71	83
10	58	66
1	----	46

APPENDIX 4

Control of Decay in Pears with SOPP and Chlorine

Appendix 4 a-c

Experiments with Pears Inoculated with Spores and Treated with Chlorine or SOPP Simultaneously

Appendix 4a

Control of Mucor Rot in Anjou Pears

METHODS

Suspensions of *M. piriformis* spores (5 x 10^6 spores/ml) were prepared in 25 gallons of water. Boxes of Anjou pears, each pear with a fresh 3 millimeter x 3 millimeter puncture, were subjected to one of the following treatments:

(i) One minute submersion in spore suspension only.

(ii) One minute submersion in spore suspension followed by a 30 second water rinse.

(iii) One minute submersion in spore suspension amended with 6% sodium hypochlorite (to contain 100 parts per million chlorine in solution; pH = 8.8) followed by a 30 second water rinse.

(iv) One minute submersion in spore suspension amended with SOPP (to contain 0.6 percent SOPP-tetrahydrate in solution) followed by a 30 second water rinse.

Four boxes of pears were used for each treatment. Addition of chlorine or SOPP to the spore suspensions was 30 seconds before treating the first box. The spores were held in suspension throughout the treatment by continuous agitation with a submersible pump. After treatment, the fruit was allowed to drip dry. It was then transferred to polyethylene-lined boxes and placed in storage at 30 degrees Fahrenheit for 43 days.

RESULTS

Treatment	Rinse	No. pears	% Decay	% Control
M. piriformis in water	No	579	68.4	0.0
M. piriformis in water	Yes	603	53.4	21.9
M. piriformis in chlorine	Yes	528	8.9	87.0
M. piriformis in SOPP	Yes	581	48.4	29.2

Appendix 4b

Control of Blue-Mold Rot in Bosc Pears

METHODS

The general methods and treatments used were described in Appendix 4a with the following exceptions: Treatment solutions were made to contain 6.1 x

10^5 spores/ml of *Penicillium expansum.* Five boxes of Bosc pears, each pear with a 3 millimeter x 3 millimeter puncture, were used for each treatment. The SOPP treatment was prepared so it contained 0.5 percent SOPP-tetrahydrate in solution.

RESULTS

Treatment	Rinse	No. pears	% Decay	% Control
P. expansum in water	No	469	37.3	0.0
P. expansum in water	Yes	509	20.8	44.2
P. expansum in chlorine	Yes	500	10.2	72.6
P. expansum in SOPP	Yes	516	17.6	52.8

Appendix 4c

Control of Mucor Rot in Bartlett Pears

METHODS

The general methods and treatments used were described in Appendix 4a with the following exceptions: Treatment solutions contained 2.4 x 10^5 spores of *M. piriformis* per millileter. Five boxxes of Bartlett pears, each pear with a 3 millimeter x 3 millimeter puncture, were used for each treatment. After treatment, the boxes were covered with polyethylene and stored at room temperature (65 to 70 degrees fahrenheit) for 7 days.

RESULTS

Treatment	Rinse	No. pears	% Decay	% Control
M. piriformis in water	No	703	53.9	0.0
M. piriformis in water	Yes	641	46.3	14.1
M. piriformis in chlorine	Yes	706	20.2	62.5
M. piriformis in SOPP	Yes	724	24.2	55.1

Appendix 4d-e

Experiments with Pears Inoculated with Spores Followed by Treatment with Chlorine or SOPP

Appendix 4d

Control of Blue-Mold Rot in Anjou Pears

METHODS

Boxes of Anjou pears, each pear with a fresh 3 millimeter x 3 millimeter puncture, were given a 1 minute submersion in a 25-gallon solution of 7.0 x 10^5 *Penicillium expansum* spores/ml. The spores were maintained in suspension by continuous agitation with a submersible pump. The fruit was allowed to dry for 3 hours. It was then given one of the following treatments in 25 gallons:

(i) One minute submersion in water only.

(ii) One minute submersion in water followed by a 15 second water rinse.

(iii) One minute submersion in 100 ppm chlorine; pH = 8.9 (prepared from 6 percent sodium hypochlorite) followed by a 15 second water rinse.

(iv) One minute submersion in SOPP (0.5 percent SOPP-tetrahydrate in solution) followed by a 15 second water rinse.

Six boxes of pears were used in the unrinsed treatment and eight boxes were used in all the others. After treatment, the fruit was allowed to drip dry. It was then packed in polyethylene lined boxes and stored at 30 degrees Fahrenheit for 25 days.

RESULTS

Treatment	Rinse	No. pears	% Decay	% Control
Water	No	540	96.2	0.0
Water	Yes	676	97.7	–1.6
Chlorine	Yes	896	98.2	–2.1
SOPP	Yes	939	67.4	29.9

Appendix 4e

Control of Mucor Rot in Anjou Pears

METHODS

The general methods and treatments used were as described in Appendix 4d with the following exceptions: Inoculum consisted of a suspension of 2.5 x 10^4 *M. piriformis* spores/ml in 25 gallons. Eight boxes of pears were used for each treatment.

RESULTS

Treatment	Rinse	No. pears	% Decay	% Control
Water	No	906	99.5	0.0
Water	Yes	934	94.4	4.1
Chlorine	Yes	963	94.2	5.3
SOPP	Yes	727	81.8	18.8

APPENDIX 5

Relationship of Exposure Time, Temperature, and Salt Concentration to Injury of Anjou Pears with SOPP Solutions

Appendix 5a

Experiments with 30 Degrees Fahrenheit Initial Fruit Temperature

METHODS

Solutions of sodium sulfate, sodium carbonate (soda ash), and sodium silicate were prepared at various concentrations. Sodium o-phenylphenate (SOPP) was added to these solutions at rates recommended by the manufacturer. Anjou pears were allowed to lie in these solutions for various lengths of time at different temperatures. Removed from solution, the pears were rinsed with tap water, blot-dried, and set at room temperature (68 to 72 degrees Fahrenheit) for 7 days. Four or five pears were used in each treatment. Similar experiments were repeated several times.

RESULTS

Temperature (°F)			Injury ratings for SOPP combined with various conc. of floatation salts[a]						
				7½ %	Sodium sulfate			Soda ash	
Air	Ave. solution	Exposure time (min.)	Distilled Water	Sodium silicate	2%	4%	6%	3%	5%
60	55.9	15	0	0	0	0	2	2	3
60	51.4	30	0	0	0	0	3	3	2
60	50.1	60	0	0	0	2	3	4	4
60	53.6	120	2	0	2	4	5	5	5
55	51.4	15	0	0	0	0	0	0	0
55	47.7	30	0	0	0	0	1	0	1
55	46.9	60	0	0	0	2	3	3	3
55	49.4	120	2	0	2	3	5	5	5
50	48.0	15	0	0	0	0	0	0	0
50	45.8	30	0	0	0	0	1	0	0
50	44.0	60	0	0	0	2	3	2	1
50	45.8	120	2	0	2	4	4	4	4
45	43.4	15	0	0	0	0	0	0	0
45	41.8	30	0	0	0	0	0	0	0
45	40.8	60	0	0	0	0	0	0	0
45	41.7	120	2	0	1	2	3	3	3

[a] Injury rating: 0 = no injury; 1 = very slight injury; 2 = some obvious injury; 3 = moderate injury; 4 = severe injury; 5 = very severe injury. Ratings 2-5 would be culled out of commercial packs.

Appendix 5b

Experiments with Fruit Allowed to Warm to the Solution Temperature Before Treatment

METHODS

The methods used were the same as in Appendix 5a except the pears were allowed to warm from 30 degrees Fahrenheit to the solution temperature before treatment. SOPP in 4 percent sodium sulfate was the only solution used.

RESULTS

Air temperature (°F)	Average solution temperature (°F)	Exposure time (min.)	Injury rating[a]
60	59.0	15	0
60	59.0	30	0
60	59.0	60	3
60	59.0	120	5
55	54.8	15	0
55	54.8	30	0
55	54.8	60	2

(Continued)

[a] Injury ratings: 0 = no injury; 1 = very slight injury; 2 = some obvious injury; 3 = moderate injury; 4 = severe injury; 5 = very severe injury. Ratings 2-5 would be culled out of commercial packs.

RESULTS (Continued)

Air temperature (°F)	Average solution temperature (°F)	Exposure time (min.)	Injury rating[a]
55	54.8	120	3
50	47.5	15	0
50	47.5	30	0
50	47.5	60	2
50	47.5	120	3
45	44.0	15	0
45	44.0	30	0
45	44.0	60	1
45	44.0	120	2

APPENDIX 6

The pH of Various Solutions Used in Packinghouse Dump Tanks

	Tap water	Sodium sulfate[a] 6%	Sodium silicate 7½%	Soda ash 5%
Tap water[b]	7.4	4.4, 6.5	......	......
SOPP (Stop-Mold F at 0.5% tetrahydrate)[c]	11.8	10.4, 10.7	......	......
SOPP (Steri-Seal at 0.3% tetrahydrate)[d]	11.5	9.7, 10.4	11.2	10.2
Chlorine 100 ppm[e]	8.8	7.8	......	......
Chlorine 150 ppm[e]	8.9	7.8	......	......

	Distilled water	Sodium sulfate[a] 6%	Sodium silicate 7½%	Soda ash 5%
Distilled water	5.8	4.0, 5.2	11.4	10.2
SOPP (Stop-Mold F at 0.5% tetrahydrate)[c]	11.8	10.6, 10.8	11.2	10.2
SOPP (Steri-Seal at 0.3% tetrahydrate)[d]	11.9	9.8, 11.2	11.3	10.0
Chlorine 100 ppm[e]	10.4	7.5, 7.6	11.2	10.0
Chlorine 150 ppm[e]	10.2	7.7, 7.8	11.2	9.9

[a] Sodium sulfate manufactured by various processes has different pH values in solution. The values above are means for sodium sulfate from two sources.

[b] pH of tap water varies with source. These values are for tap water at the Duckwall-Pooley Fruit Co. packinghouse in Odell, Oregon.

[c] Stop-Mold F: Gwin, White and Prince, Inc., Seattle, WA 98115.

[d] Steri-Seal: Steri-Seal Corp., Wenatchee, WA 93801.

[e] Chlorine solutions prepared from 6 percent sodium hypochlorite.

APPENDIX 7

Fungicidal Action of Chlorine Combined with Floatation Salts

METHODS

Chlorine solutions (100 parts per million chlorine) were prepared from 6 percent sodium hypochlorite in distilled water, 7½ percent sodium silicate, and 6 percent sodium sulfate. At time zero, spores of *Penicillium expansum* were added to the solutions. At various time intervals thereafter (2.5, 5, 10, 20 minutes), 0.1 milliliter samples were withdrawn and spread on potato dextrose agar. Two agar plates were used for each treatment each time. The agar plates were set at room temperature for 7 to 10 days and colony counts were made. Each distinct colony was counted as one viable spore.

RESULTS

	No. viable spores per ml			
	2.5 min.	5 min.	10 min.	20 min.
Chlorine in water	80	2.5	0	0
Water only	96,000	104,000	102,000	136,000
Chlorine in sodium silicate	2,590	1,960	1,450	0
Sodium silicate only	102,000	138,000	134,000	116,000
Chlorine in sodium sulfate	2.5	2.5	0	0
Sodium sulfate only	108,000	94,000	80,000	90,000