Use of Surfactants with Chlorine to Improve Pear Decay Control

R. A. SPOTTS, Associate Professor, Department of Botany and Plant Pathology, and B. B. PETERS, Experimental Biology Technician, Oregon State University, Mid-Columbia Experiment Station, Hood River 97031

ABSTRACT

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The effectiveness of several surfactants added to a solution containing 50 μg of total available chlorine per milliliter at pH 10.9 and held at 10 C to reduce d'Anjou pear (*Pyrus communis*) decay is reported. Although chlorine alone did not reduce decay caused by *Botrytis cinerea* or *Mucor piriformis* in puncture-wounded d'Anjou pear fruits, addition of Ortho X77, Triton X100, or VWR Spread No. 1 to chlorinated dump tank water containing 5.0% sodium silicate significantly improved decay control for *B. cinerea, M. piriformis*, and *Penicillium expansum* when compared with chlorine alone. Chlorinated water containing Ortho X77 and VWR Spread No. 1 effectively controlled *M. piriformis* decay for 3 wk. Addition of Ortho X77, Triton X100, or VWR Spread No. 1 to nonchlorinated water resulted in increased decay. Surfactant effects did not result from pH changes but appeared related to improved penetration of chlorine into wounds.

Chlorine has been used to control decay of apples since 1932 (2) and was shown to effectively control decay of stone fruits (6) and citrus (5). Chlorine is often used to reduce decay in commercial pear packinghouses in the Pacific Northwest. When *Botrytis cinerea* Pers. ex Fr., *Mucor piriformis* Fischer, and *Penicillium expansum* Lk. ex Thom conidia were exposed to chlorine at 50 μg/ml for 5 min, no conidial germination or d'Anjou pear decay occurred (8). However, chlorine gave poor decay control when used after inoculation (3,8), apparently because of failure of the chlorine to penetrate and kill spores lodged in wounds.

Surfactants are a broad group of compounds used in various formulations to reduce surface tension of aqueous solutions. Presently, no surfactants are used in pear packinghouse dump tank water.

This study evaluated the effectiveness of several surfactants to improve penetration of chlorine and reduce d'Anjou pear decay.

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MATERIALS AND METHODS

Evaluation of surfactants. Solutions containing 0.5% active ingredient (a.i.) (v/v) of each of 15 surfactants (Table 1) were prepared in distilled water at 10 C. Solutions were chlorinated with commercial bleach containing 5.25% sodium hypochlorite (NaOCl) and adjusted to 56 ± 11 μg of total available chlorine per milliliter. Chlorine concentration was determined by sodium thiosulfate titration (1). In preliminary experiments, surfactant concentrations less than 0.4% appeared less effective than those of 0.5%, and lower concentrations were not included in further studies.

B. cinerea, M. piriformis, and *P. expansum* were grown on acid (pH 3.7 obtained with 1.5 ml of 85% lactic acid per liter) potato-dextrose agar (Difco Laboratories, Detroit, MI 48232). Cultures 7 to 14 days old were flooded with sterile distilled water, and suspensions were adjusted to obtain 1.0, 2.0, and 10.0×10^3 conidia of *P. expansum, B. cinerea*, and *M. piriformis* per milliliter, respectively.

D'Anjou pear (*Pyrus communis* L.) fruits were surface sterilized with NaOCl, then rinsed and puncture-wounded (3 mm diameter, 4 mm deep at three locations per fruit) with the head of a finishing nail. Inoculum of each fungus was placed in the wounds (0.028 ml) and dried 1 hr. Inoculated fruits were

immersed in the surfactant-chlorine solutions for 5 min, rinsed with tap water, then placed in polyethylene-lined boxes at 18 ± 2 C for 5–9 days and evaluated for decay as percentage of decayed wounds per replicate fruit. Both distilled water and chlorine without surfactant treatments were included as controls.

Surfactants in dump tank water. Solutions containing 0.5% a.i. of each of the four surfactants (Table 2) found most effective in the initial evaluation were prepared using autoclaved water from a commercial packinghouse dump tank. This water contained approximately 5.0% sodium silicate, a common pear flotation agent. Surfactant solutions were chlorinated with commercial bleach (57 ± 6 μg/ml) and cooled to 10 C, and inoculum was added to obtain the spore concentrations stated previously. Wounded d'Anjou pear fruits were immersed 5 min in the solutions, rinsed with water, and stored for decay evaluations.

Duration of effectiveness of Ortho X77 and VWR Spread No. 1 was studied over a 3-wk period. Chlorinated surfactant (0.5% a.i.) solutions (57 ± 6 μg/ml) were prepared with nonautoclaved dump tank water containing approximately 5.0% sodium silicate. *M. piriformis* conidia were added to the solutions to obtain 7,500 ± 500 conidia per milliliter. Wounded d'Anjou pear fruits were immersed 5 min in the solutions, rinsed with water, then incubated as described previously. Prior to fruit immersion, chlorine concentration was determined, then adjusted with sodium thiosulfate or NaOCl, but no changes in surfactant were made during the 3 wk. Because viable *M. piriformis* spores were not recovered after 24 hr in these solutions, fresh inoculum was added weekly prior to immersing fruits. At the conclusion of the experiment, the pH of all solutions was measured with a Corning model 7 pH meter (Corning Glass Works, Corning, NY 14830).

Effect of surfactants without chlorine on decay. To study the effects of surfactant solutions without chlorine on pear decay, wounded, surface-sterilized d'Anjou pear fruits were immersed for 5 min in distilled water at 10 C and containing 0.5% Triton X100, VWR Spread No. 1, or Ortho X77. Each surfactant solution contained *P. expansum, B. cinerea*, or *M. piriformis* at 1.0, 2.0, and 10.0 × 10^3 conidia per milliliter, respectively. Following treatment, decay was evaluated as described previously.

RESULTS

Addition of Ortho X77, Triton X100, Amway Adjuvant, or Bio-film to chlorine resulted in significant ($P = 0.05$) control of *M. piriformis* decay; addition of Ortho X77, VWR Spread No. 1, or Amway Adjuvant to chlorine provided significant ($P = 0.05$) *P. expansum* decay control (Table 1). Addition of Ortho X77, Triton X100, Triton X114, VWR Spread No. 1, or Triton N101 to chlorine resulted in significant ($P = 0.05$) control of *B. cinerea* (Table 1). Chlorine alone failed to give significant ($P = 0.05$) *M. piriformis* or *P. expansum* decay control when compared with water but provided significant *B. cinerea* control (Table 1).

When four of the more effective surfactants were tested in commercial packinghouse dump tank water containing chlorine and inoculum (added immediately prior to immersing wounded pear fruits), Ortho X77, Triton X100, and VWR Spread No. 1 significantly ($P = 0.05$) improved decay control for all fungi tested when compared with chlorine alone (Table 2). Amway Adjuvant significantly ($P = 0.05$) improved the effectiveness of chlorine for control of *M. piriformis* and *P. expansum* but not *B. cinerea* decay (Table 2).

When Ortho X77 and VWR Spread No. 1 were tested over a 3-wk period in

Table 1. Effect of surfactant additives to chlorine on decay of inoculated d'Anjou pears

Treatment[y]	Manufacturer	Percentage of decay[z] caused by		
		B. cinerea	*M. piriformis*	*P. expansum*
Ortho X77	Chevron Chemical	0 a	12.5 a	47.5 a
Triton X100	Rohm and Haas	0 a	13.3 a	79.2 cde
Triton X114	Rohm and Haas	6.7 a	20.8 abc	87.5 de
Triton N101	Rohm and Haas	8.3 a	30.8 abc	75.0 bcde
VWR Spread No. 1	Van Waters and Rogers	15.8 a	20.0 abc	57.5 abc
Triton X305	Rohm and Haas	39.2 b	50.8 bc	95.8 e
Ag-foam	Thompson-Hayward Chemical	40.0 b	26.7 abc	83.3 cde
Triton X405	Rohm and Haas	44.2 b	27.5 abc	95.8 e
R11	Rhodes Chemical	47.5 b	20.8 abc	65.0 abcd
Amway Adjuvant	Amway	48.3 b	9.2 a	50.8 ab
Multi-film	Colloidal Products	62.5 bcd	25.8 abc	80.8 cde
Potato Kleen 211	Pennwalt	75.8 cde	25.0 abc	66.7 abcd
Bio-film	Kalo Agricultural	91.7 e	16.7 ab	65.8 abcd
Regulaid	Kalo Agricultural	93.3 e	20.8 abc	86.7 de
B1956	Rohm and Haas	97.5 e	29.2 abc	91.2 de
Water check	···	79.2 de	55.0 c	87.5 de
Chlorine check	···	54.2 bc	27.5 abc	69.2 abcde

[y] Fruits immersed in chlorinated 0.5% a.i. surfactant solution at 10 C following inoculation with 1.0, 2.0, or 10.0 × 10^3 conidia of *Penicillium expansum, Botrytis cinerea,* or *Mucor piriformis* per milliliter, respectively. Solutions contained 56 ± 11 μg of total available chlorine per milliliter.
[z] Each value represents the mean of 10 fruits, each wounded three times. Numbers followed by the same letter within columns are not significantly different at $P = 0.05$ according to Duncan's new multiple range test.

Table 2. Effect of surfactants on d'Anjou decay control in chlorinated commercial dump tank water

Treatment[y]	Percentage of decay[z] caused by		
	B. cinerea	*M. piriformis*	*P. expansum*
Ortho X77	0 a	0 a	0 a
Triton X100	0 a	3.3 a	0 a
VWR Spread No. 1	0 a	6.1 a	3.3 a
Amway Adjuvant	3.3 ab	10.0 a	6.7 a
Chlorine check	13.3 b	33.3 b	26.7 b
Water check	13.3 b	40.0 b	56.7 c

[y] Each surfactant solution contained 0.5% a.i. surfactant, total available chlorine at 57 ± 6 μg/ml, and 1.0, 2.0, or 10.0 × 10^3 conidia of *Penicillium expansum, Botrytis cinerea,* or *Mucor piriformis* per milliliter, respectively. All solutions were made with autoclaved packinghouse dump tank water containing 5.0% sodium silicate and were adjusted to 10 C.
[z] Each value represents the mean of 10 fruits, each wounded three times. Numbers followed by the same letter within columns are not significantly different at $P = 0.05$ according to Duncan's new multiple range test.

Table 3. Duration of effect of Ortho X77 and VMR Spread No. 1 on *Mucor piriformis* on d'Anjou pears in commercial dump tank water

Treatment[x]	Percentage of decay[y]			
	Age of treatment solution (wk)			
	0	1	2	3
VWR Spread No. 1[z]	9 a	8 a	6 a	2 a
Ortho X77[z]	2 a	10 a	9 a	9 a
Chlorine check	24 b	31 b	28 b	27 b
Water check	30 b	42 c	43 c	40 c

[x] Solutions made with nonautoclaved commercial dump tank water at 12 ± 1 C and containing 5.0% sodium silicate. Chlorine adjusted weekly to 57 ± 6 μg/ml. *M. piriformis* concentration adjusted to 7,500 ± 500 conidia per milliliter weekly immediately prior to immersion of wounded fruit.
[y] Each value represents the mean of 60 fruits, each wounded three times. Numbers followed by the same letter within columns are not significantly different at $P = 0.01$ according to Duncan's new multiple range test.
[z] After initial surfactant addition at 0 wk to obtain 0.5% a.i. surfactant, no additional surfactant was added.

Table 4. Effect of surfactants without chlorine on d'Anjou pear decay

Treatment[y]	Percentage of decay[z] caused by		
	B. cinerea	*M. piriformis*	*P. expansum*
Water	47 a	27 a	20 a
VWR Spread No. 1	67 ab	70 b	20 a
Triton X100	67 ab	63 b	37 a
Ortho X77	80 b	67 b	37 a

[y]Wounded fruits immersed in 0.5% a.i. surfactant solution made with distilled water at 10 C containing 1.0, 2.0, or 10.0×10^3 conidia of *Penicillium expansum, Botrytis cinerea,* or *Mucor piriformis* per milliliter, respectively.

[z]Each value represents the mean of 10 fruits, each wounded three times. Numbers followed by the same letter within columns are not significantly different at $P = 0.05$ according to Duncan's new multiple range test.

chlorinated dump tank water, both surfactants significantly ($P = 0.01$) improved *M. piriformis* decay control compared with chlorine alone (Table 3). The surfactants were as effective after 3 wk as at the beginning of the study. No significant difference in decay control between Ortho X77 and VWR Spread No. 1 was observed. The pH of dump tank water alone or containing chlorine plus either surfactant was 10.9. The pH of chlorinated dump tank water with no surfactants was 11.0.

When wounded fruits were immersed in distilled water containing inoculum plus surfactant but no chlorine, a trend toward increased *B. cinerea* and *P. expansum* decay was observed compared with water without surfactant (Table 4). Significantly more ($P = 0.05$) *M. piriformis* decay occurred in fruit immersed in water containing Ortho X77, Triton X100, or VWR Spread No. 1 than in water without surfactant, and addition of Ortho X77 to water resulted in significantly more ($P = 0.05$) *B. cinerea* decay (Table 4).

DISCUSSION

Although chlorination of packinghouse dump tank water has improved decay control by lowering dump tank spore loads, chlorine apparently does not penetrate small wounds and stem or calyx areas of pear fruits, and spores lodged in these areas may cause decay. In this study, several surfactants effectively improved the decay control potential of chlorine and may be of great value to the fruit industry. When wounded fruits were immersed in water containing chlorine and inoculum, addition of several surfactants improved decay control. Even when spores were placed directly into puncture wounds, chlorine plus various surfactant solutions reduced decay more than chlorine alone.

Two surfactants tested were effective for at least 3 wk. Because this is usually the maximum duration between dump tank water changes in packinghouses, addition of surfactant would only be necessary during the initial preparation, although replacement of solution lost from bin and fruit removal or through evaporation must be considered.

Previous work has shown that fungicidal effectiveness of chlorine is dependent on pH (4,7). Surfactants in this study did not alter dump tank water pH and appeared to act primarily to improve penetration of chlorine into wounds. When surfactants were used without chlorine, spore penetration into wounds appeared to be enhanced, and decay increased. Thus, in a commercial situation, careful monitoring of chlorine concentration would be important to obtain beneficial rather than detrimental effect from surfactants.

When d'Anjou pear fruits were immersed in 0.5% Ortho X77 or VWR Spread No. 1 and stored at −1.1 C without rinsing, no adverse effects on fruit finish were observed at 2 mo. In packinghouses, all fruit is rinsed when removed from the dump tanks or flumes.

LITERATURE CITED

1. American Public Health Association. 1975. Standard Methods for Examination of Water and Waste Water. 14th ed. New York. pp. 316-318.
2. Baker, K. F., and Heald, F. D. 1932. Some problems concerning blue mold in relation to cleaning and packing apples. Phytopathology 22:879-898.
3. Bertrand, P., and Saulie-Carter, J. 1979. Postharvest decay control of apples and pears after immersion dumping. Org. Agric. Exp. Stn. Spec. Rep. 545. 9 pp.
4. Combrink, J. C., Matthee, F. N., and Kock, J. S. 1980. Stability of sodium hypochlorite solutions and their effectiveness against conidia of *Penicillium expansum* Thom. Phytophylactica 12:85-87.
5. Hall, D. J., and Bice, J. R. 1977. Packinghouse strategies for the control of fungicide resistant molds. Proc. Fla. State Hortic. Soc. 90:138-141.
6. Phillips, D. J., and Grendahl, J. 1973. The effect of chlorinating hydrocooling water on *Monilinia fructicola* conidia and brown rot. Plant Dis. Rep. 57:814-816.
7. Segall, R. H. 1968. Fungicidal effectiveness of chlorine as influenced by concentration, temperature, pH, and spore exposure time. Phytopathology 58:1412-1414.
8. Spotts, R. A., and Peters, B. B. 1980. Chlorine and chlorine dioxide for control of d'Anjou pear decay. Plant Dis. 64:1095-1097.