Ultrasound Treatments to Control Surface Pests of Fruit

James D. Hansen

Additional index words. *Cydia pomonella*, codling moth, T*etranychus urticae*, twospotted spider mite, *Frankliniella occidentalis*, western flower thrips, *Quadraspidiotus perniciosus*, san jose scale, phytosanitation

Summary. **Durations of ultrasound treatments were evaluated for efficacy in removing or destroying external pests of apples (*Malus sylvestris* var *domestica*). Egg hatch of codling moth (*Cydia pomonella*; Lepidoptera: Tortricidae), was inversely related to time of ultrasound exposure, although egg mortality was less than 60% after 45 min of treatment. Mortality of twospotted spider mite (*Tetranychus urticae*; Acari: Tetranychidae), and western flower thrips (*Frankliniella occidentalis*; Thysanoptera: Thripidae), was directly related to ultrasound durations; adding detergent to the ultrasound bath increased treatment efficacy. Ultrasound did not remove san jose scale (*Quadraspidiotus perniciosus*; Homoptera: Diaspididae), from the fruit surface. Ultrasound, which can be incorporated in the packing line, shows promise as a postharvest phytosanitation treatment against external pests.**

The Pacific northwestern United States produces about 70% of the fresh apples, 95% of the winter pears (*Pyrus commu-*

Agricultural Research Service, U.S. Department of Agriculture, Yakima Agricultural Research Laboratory, 5230 Konnowac Pass Road, Wapato, WA 98951.

Millie L. Heidt, Michele A. Watkins, Laura J. Rehmke, and Misty Weishaar (USDA-ARS, Wapato, Wash.) provided major technical support. I thank Carrol O.Calkins and Peter J. Landolt (USDA-ARS, Wapato, Wash.), Judy A. Johnson (USDA-ARS, Fresno, Calif.), and M. Hennessey (US-EPA, Washington, D.C.) for reviewing the manuscript. This research was supported, in part, by Northwest Fruit Exporters and the Washington Tree Fruit Research Commission. This paper reports the results of research only. Mention of a commercial product does not constitute a recommendation by the USDA. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

nis), and 70% of the sweet cherries (*Prunus avium*) in the U.S. Exports accounted for about 30% of the Pacific northwestern apple market in 1997, 35% of the winter pear market, and 32% of the sweet cherry market. Certain arthropods that occur on the fruit exterior, such as thrips (Thysanoptera) and mites (Acari), are important quarantine pests. For example, recent shipments of apples were halted at Brazilian ports on suspicion of having prohibited species of thrips or mites. Furthermore, mealybugs (Homoptera) and scales (Homoptera) may cause problems when encountered by inspectors on fruit intended for export.

Regulatory changes involving chemical treatments and international concern about the introduction of new pests demand that innovative methods be examined to assist in the phytosanitation process. These methods should be compatible with existing operations, simple, and inexpensive. Hence, the packing line can be improved by incorporating procedures to prevent the introduction of unwanted pests.

Ultrasound or other forms of mechanical disturbance may have application for disinfesting fruit of quarantine pests. Ultrasound is produced by a transducer containing a ceramic crystal; a short pulse (about 100 ns) of voltage is converted to a short sound pulse (1 s) at the fundamental frequency of the transducer (Cartwright, 1997). In a liquid, alternating high and low pressure waves generated by the high frequency sound causes the rapid formation and collapse of millions of tiny bubbles, which is called cavitation (Sala et al., 1999). Commercial ultrasound equipment uses energy released by cavitation to clean surface structures. Sometimes a cleaning agent is added to increase efficacy. Furthermore, the use of ultrasound is detrimental to a variety of organisms. It has been shown to lyse cells in leaves of a pond weed (*Elodea* sp.) (Carstensen et al., 1990b), kill larvae of vinegar flies (*Drosophila* sp.) (Carstensen et al., 1990a, Child et al., 1992), and break chromosomes in drosophilid larvae (Tsaka, 1982).

Commercial ultrasound devices are made according to a range of specifications for a variety of uses, from cleaning jewelry to aging liquors (Sala et al., 1999). The purpose of this study was to investigate the use of a simple cleaning unit to indicate the potential of ultrasound as a postharvest treatment. Ultrasound effects were examined on the viability of codling moth eggs or for removing external pests from fruit surfaces.

Materials and methods

Treatments. Ultrasonic treatments were conducted in the laboratory using a ultrasonic cleaner (ADC 5002; Bransonic Cleaning Equipment Co.; Shelton, Conn.). The apparatus operated at 50/60 Hz, 117 V, and 1.0 amperes. Fruit, infested with surface pests listed below, were treated submerged for various times in a bath of distilled water [2.1 qt (2 L)]. To determine if detergent enhances the effectiveness of ultrasound, Ultra Dawn Dishwashing Detergent (Procter and Gamble; Cincinnati, Ohio), a nonfood grade surfactant, was added at a rate of 0.0064 oz/gal of water (0.05 $mL{\cdot}L^{-1}$); this material was selected to represent detergents as a category and can not be used under packing house conditions. Controls were indicated by 0-min treatments. All surface pests, except scales, were treated on organically grown ‘Delicious’ apples. Scale insects were obtained on fruit from a feral apple tree of unknown lineage.

Insects examined. Eggs of the codling moth were obtained from adult females, reared from an established colony (USDA-ARS, Yakima Agricultural Research Laboratory, Wapato, Wash.), ovipositing on apples. When eggs reached blackhead stage, they were counted, then treated for 0, 15, 30, or 45 min. Each apple was treated separately to prevent eggs from being rubbed off by adjoining fruit. The total number of eggs per treatment ranged from 50 to 80. Eggs were held at 25 °C (77 °F) for about 1 week, then the number of hatched eggs counted. The test was replicated three times.

Nymphs and adults of the western flower thrips were obtained by sweep netting in an alfalfa field (Washington State University Experimental Farm, Prosser, Wash.). In the laboratory, the insects were placed in cylindrical cardboard containers [6.5 inches diameter × 6.25 inches height (16.5 cm diameter × 15.9 cm height)], each containing five apples, and the insects were allowed to disperse during the night. Each apple was treated separately for 0, 1, 5, 10 min or for 10 min with detergent treatment. Immediately after treatment, each apple was placed in a separate plastic bag, frozen, then the number of thrips in the bag were counted the next day. Test sets with controls having less than 10 thrips before treatment were rejected because of insufficient number of insects. This test was replicated 11 times.

A laboratory colony of the twospotted spider mite was established using seedlings of the pinto bean (*Phaseolus vulgaris*). Apples were infested with adult mites by placing the apples on the bean plants and allowing the mites to crawl onto the fruit overnight. The mite-infested apples were subjected to the same treatments as the thrips. After treatments, apples were placed in separate bags and frozen. Efficacy was determined by counting the number of mites in the bags. This test was replicated seven times.

Apples from the field, infested with san jose scale, were separated into five groups, each with roughly the same number of insects. Ultrasound treatments were 0, 1, 5, and 10 min, and 10 min with detergent. Three days later, the scales remaining on the apples were counted according to treatment. This test was replicated five times.

Data analysis. Data were analyzed with the Statistical Analysis System (SAS Institute, 1989). PROC MEANS was used for data summary. Nonparametric tests were used to determine significant differences by first arranging data by PROC RANK, then conducting the equivalent to the Kruskal-Wallis k sample test by using PROC GLM with LSD means separation (SAS Institute, 1989; Zar, 1974).

Results and discussion

Throughout this study, no appar-

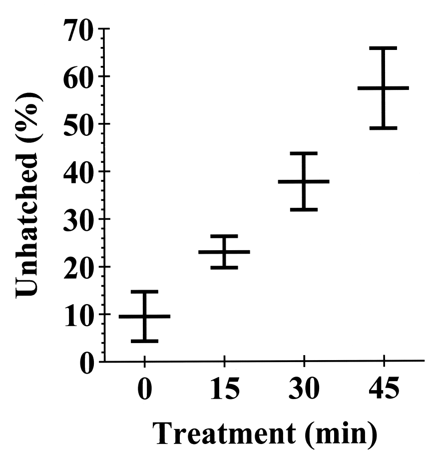

Fig. 1. Mean (±SE) egg hatch of codling moth on apple after various durations of ultrasound treatment in water bath.

Table 1. Retension (number of live individuals per replicate) of western flower thrips and twospotted spider mites on apple fruit after ultrasound treatments (at 50/60 Hz, 117 V, and 1.0 amperes) of various durations.

Treatment	Western flower thrips			Twospotted spider mites		
(min)	Mean	SE	Replication	Mean	SE	Replication
0 (control)	38.8	6.6	11	44.0	18.2	7
1	19.6	5.7	11	24.0	8.1	7
5	13.1	2.2	11	19.7	4.8	7
10	8.0	1.8	11	9.7	3.3	7
10 + detergent	6.2	1.6	11	1.8	0.3	7

ent injury or phytotoxicity was observed on the fruit due to the ultrasound exposures, even for the longest durations. Cavitation occurs in the water bath but probably does not extend into the fruit epidermis (Hansen et al., 1992; Hayes et al., 1983). Furthermore, no appreciable heat was detected by the operator on the fruit or in the bath water during any of the exposures. These promising results suggest that large amounts of fruit could be treated simultaneously in a commercial setting without causing phytotoxic effects, but further examination of appropriate large-scale ultrasound machines is necessary.

Codling moth egg hatch was affected by duration of ultrasound exposure (Fig. 1). Significant differences in percent hatch were found among the treatments ($F = 12.39$, df = 3,8; $P < 0.01$). However, even at the longest duration (45 min), average mortality was less than 60%, with no apparent egg removal. Ultrasound treatment would be impractical for treating only codling moth eggs, but further evaluations are needed on the effect on eggs of other species. Also, more powerful machines may increase efficacy.

Both the mites and thrips were adversely affected by treatments (mites: $F = 12.09$, df = 4,30; $P < 0.01$; thrips: $F = 10.67$, df = 4,50; $P < 0.01$). Removal of the pest from the fruit surface was directly related to time of exposure (Table 1). The detergent treatment further impacted removal, particularly for spider mites. The 10 min treatment duration may be too long in a commercial packing line, but may be practical as a holding treatment for those lots that have field infestation problems.

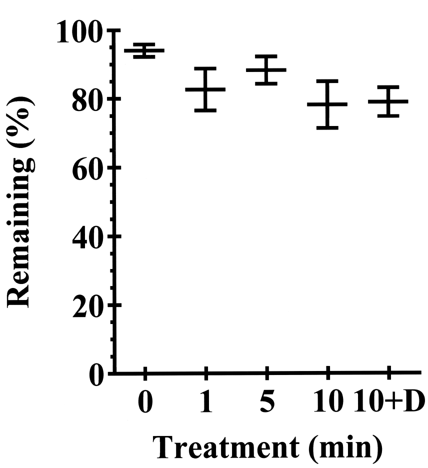

Fig. 2. Mean (±SE) percent san jose scales remaining on apple after various durations of ultrasound treatment in water bath; D = detergent.

The ultrasound treatments were ineffective against san jose scale ($F = 2.19$, df = 4,20; $P > 0.05$) based upon presence immediately after treatment. Even the detergent treatment did not contribute to mortality (Fig. 2). Scales are uniquely structured insects, and perhaps the cuticle minimizes the effect of cavitation. Perhaps a more powerful ultrasound unit could remove the scales from the fruit surface.

Ultrasound shows promise as one of the methods to contribute to assuring pest-free product for export. The practicality of implementing ultrasound in a commercial setting deserves further examination. For example, ultrasound treatments could be incorporated in a dip within the packing line. As a component of the Systems Approach (Jang and Moffitt, 1994), ultrasound treatments can help eliminate some surface pests where the commercial postharvest process has a cumulative effect in phytosanitation. Ultrasound units more powerful than the one tested in this study may have the capacity to eliminate scales and eggs on the fruit surface. Finally, the ultrasound treatments could be used with organic fruit without jeopardizing their organic labeling.

Literature cited

Carstensen, E.L., D.S. Campbell, D. Hoffman, S.Z. Child, and E.J. Ayme-Bellegarda. 1990a. Killing *Drosophila* larvae by the fields of an electrohydraulic lithotripter. Ultrasound Medicine Biol. 16:687–698.

Carstensen, E.L., S.Z. Child, C. Crane, M.W. Miller, and K.J. Parker. 1990b. Lysis of cells in Elodea leaves by pulsed and continuous wave sound. Ultrasound Medicine Biol. 16:167–174.

Cartwright, D. 1997. 'Off-the-shelf' ultrasound instrumentation for the food industry, p. 17–29. In: M.J.W. Povey and T.J. Mason (eds.). Ultrasound in food processing. Blackie Academic & Profession, New York.

Child, S.Z., C.H. Raeman, E. Walters, and E.L. Carstensen. 1992. The sensitivity of *Drosophila* larvae to continuous-wave ultrasound. Ultrasound Medicine Biol. 18:725–728.

Jang, E.B. and H.R. Moffitt. 1994. The systems approach to achieving quarantine security, p. 225–237. In: J.L. Sharp and G.J. Hallman (eds.). Quarantine treatments for pests of food plants. Westview Press, Boulder, Colo.

Hansen, J.D., C.L. Emerson, and D.A. Signorotti. 1992. Visual detection of sweetpotato weevil by non-invasive methods. Fla. Entomol. 75:369–375.

Hayes, C.F., H.T.G. Chingon, M.B. McMurdo, M.B. Ikeda, S.L. Sanderson, and J. Deaver. 1983. Ultrasonic effects on *Dacus dorsalis*. Ultrasound Medicine Biol. 9:185–189.

Sala, F.J., J. Burgos, S. Condón, P. Lopez, and J. Raso. 1999. Effect of heat and ultrasound on microorganisms and enzymes, p. 176–204. In: G.W. Gould (ed.). New methods of food preservation. Chapman & Hall, New York.

SAS Institute Inc. 1989. SAS/STAT user's guide, release 6.11 edition. SAS Institute Inc., Cary, N.C.

Tsaka, S.C. 1982. Chromosomal breaks and aberrations observed after applying ultrasound to *Drosophila subobscura*. Genetica 60:77–80.

Zar, J.H. 1974. Biostatistical analysis. Prentice-Hall, Englewood Cliffs, N.J.