Populations of propagules of *Mucor* spp. during immersion dumping of Anjou pears

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Water used for immersion dumping of Anjou pears was sampled for *Mucor piriformis* at a commercial packinghouse. Untreated and filtered water contained an average of 62.6 and 126.0 propagules/ml *Mucor* spp. respectively. This was 4.9 and 9.8 times more than was found in chlorinated (50-100 µg/ml available chlorine) dump-water which contained an average of 12.6 propagules/ml. The importance of dump-water sanitation for the control of rot caused by *Mucor piriformis* is discussed.

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On a échantilloné l'eau utilisée pour la vidange par immersion des poires Anjou pour la présence de *Mucor piriformis* dans un établissement d'emballage commercial. L'eau non traitée et filtrée contenait en moyenne 62,6 et 126,0 propagules/ml d'espèces de *Mucor* respectivement, soit 4,9 et 9,8 fois plus que dans l'eau de vidange chlorée (50 à 100 mg/ml de chlore disponible) qui contenait en moyenne 12,6 propagules/ml. Les auteurs discutent de l'importance de l'hygiène de l'eau de vidange dans la lutte contre la pourriture causée par *Mucor piriformis*.

Introduction

Mucor piriformis Fischer causes decay in pears which may be at the stem-end, at the calyx-end, in the core region or anywhere on the fruit surface (8). It was first recorded as a postharvest pathogen of Anjou pears in the Okanagan Valley in 1971 (3). Since 1971, *M. piriformis* has been identified several times, primarily on Anjou pears, but has also been identified on apples and peaches in cold storage (Sholberg, unpublished). In 1985 the pathogen caused an estimated loss of $70,000 to a British Columbia packinghouse due to decay and repacking costs.

Dobson et al. (2) showed that propagules of *M. piriformis* accumulate in the orchard on infected fallen fruit and become incorporated into the orchard soil. Michailides and Spotts (4) found that *M. piriformis* was absent in samples of leaves, fruit and air collected during harvest. They showed that soil adhering to picking bins was a very important source of inoculum. The fruit are inoculated with *M. piriformis* propagules when they are floated out of the picking bins into water containing soil contaminated with *M. piriformis* (5).

This study was undertaken to determine the importance of immersion water as a source of inoculum for *M. piriformis* in British Columbia and to find out if the inoculum could be reduced by filtration or chlorination under commercial operating conditions.

Materials and methods

Sampling. Dump-tank water at a commercial packinghouse in British Columbia containing sodium sulfate as a floatation salt was sampled daily during emptying of bins (360 kg/bin) of Anjou pears from storage at 0°C. Dump-tank water was sampled in 1985 on November 20 to 28; in 1986 on December 2 to 11 and in 1988 on January 19 to 22. The water was sampled by immersing a 250 ml sample bottle into a flume approximately 3 meters from the dump-tank where pears were immersed to remove them from the bins.

Populations of propagules of *Mucor* spp. and *Penicillium* spp. were monitored by taking 0.1 ml of the sampled dump-tank water and spreading it over a petri plate 50 mm in diameter containing 10 ml of potato dextrose agar (Difco, Detroit, MI) acidified with 15 ml of 85% lactic acid per liter (APDA) and incubating for 2-3 days at 10°C for *Mucor* spp. and at 25°C for *Penicillium* spp. If the dump-tank water contained chlorine the APDA plates were immediately inoculated at the packinghouse because the effect of chlorine increased with time of exposure. At least 3 plates were inoculated for each sample of dump-tank water taken. After incubation at 10°C for 2-3 days, *Mucor* spp. colonies were counted with the aid of a stereo-microscope. The colonies of *Mucor* spp. were distinguished by their stiff whisker-like appearance. *Penicillium* spp. were counted after 3 days and checked 6 days later for typical blue-green sporulation.

Filtration. The dump-tank used for the filtration study held 20,000 L of water which was filtered by using a circulating pump (Model No. RPF 700, Pac. Fab. Inc., Sanford, NC) delivering 250 L/min at 69 kPa through two Jacuzzi sand filter units (Model 24 FM-6, Jacuzzi Canada Ltd., Rexdale, Ont.) containing #16 silica sand and connected in parallel for a total surface area of 0.5574 m^2. A pressure switch automatically turned on a red signal light and shut off the circulating pump when the pressure between the intake and outlet varied by more than 69 kPa.

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The sand filter was backwashed manually with an external source of pressurized domestic water. Backwash water was sampled for *Mucor* spp. propagules on December 9 and 12, 1986 in the same manner as described above. Small amounts of water (20-50 L) were occasionally added to the dump-tank to keep the level adequate for moving fruit.

Chlorination. Dump-tank water was chlorinated by adding 12% commercial grade sodium hypochlorite to the dump-tank to maintain a concentration of 50-100 µg/ml of available chlorine in the water. This was accomplished by injecting the sodium hypochlorite in the dump-tank with an injector pump (Chem-Feed Model No. C 6125P, Blue-White Industries, Westminster, CA) which was operated when the dump-tank circulating pump was running. The pH of the dump-water was monitored daily at the packinghouse with indicator paper for a rough estimate of pH and again at the laboratory with a pH meter (Fisher Accumet pH Meter, Fisher Scientific Co., USA) to determine if buffer needed to be added to the dump-tank. A pH range of 8.0 to about 8.5 has been recommended to give the best balance between stability and effectiveness of chlorine (12). Available chlorine of the dump-tank water was measured several times each day with a colorimetric test kit (Pennwalt Corp., Monrovia, CA 91016).

Results and discussion

Propagule levels of *Mucor* spp. in untreated dump-tank water averaged 62.6 ± 74 propagules/ml (Table 1). However propagule levels ranged from 0, after the first bins of pears were dumped, to 240 when the final bins were dumped. These levels were comparable to levels previously reported by Spotts and Cervantes (11) who never found more than 427/ml. The levels of *Mucor* spp. propagules in the dump-tank are extremely variable because they depend upon the amount of soil adhering to the picking bins and concentration of *Mucor* spp. propagules in the soil (5). In a study of 51 Anjou pear orchard soils in the vicinity of the packinghouse the soil ranged from 0 to 3.45 X 10^5 propagules per gram of dry soil (6). Furthermore, not all *Mucor* spp. found in the orchard soil were pathogenic to Anjou pear. We estimate that 73.5% of the propagules in the dump-tank would be pathogenic because this value was found in the orchard soils (6).

Table 1. Number of propagules of *Mucor* spp./ml in Anjou pear dump-tank water.

Water Treatment	Date Sampled	Total Bins Emptied	Av. No. Propagules/ml
None	Nov. 20-29, 1985	792	62.6 ± 74
Filtered	Dec. 3-12, 1986	999	126.0 ± 53
Chlorinated	Jan. 19-22, 1988	497	12.8 ± 11

The filter removed propagules of *Mucor* spp. from the dump-water although the filtered water contained a higher average number of propagules than unfiltered water from the previous year (Table 1). On December 9, 1986 the backwash water contained 3633 propagules/ml and the dump-tank contained 106 propagules/ml and on December 12 the backwash water contained 2866 propagules/ml and the dump-tank contained 70. Since the backwash water contained 34.3 to 40.9 times more propagules than the filtered water in the dump-tank we concluded it was capable of removing *Mucor* spp. propagules.

Unfortunately the filter left too many *Mucor* spp. propagules in the dump-tank. On December 5, 1986 after the filter had been operating intermittently for 3 days the number of *Mucor* spp. propagules/ml reached 210 which is sufficient to decay 10% of wounded Anjou pears (9). This inoculum would also likely be enough to inoculate fruit at the stem and calyx end causing stem and calyx end rot. The filter would have to be used in conjunction with another means of removing postharvest pathogens from the dump-water in order to be effective. It may be possible to use filtration in addition to chlorination to improve the performance of the treatment. Filtered Red Delicious apple-dump-water that was chlorinated with 50-100 µg/ml chlorine contained 7.0 propagules/ml of *Penicillium* spp. compared to 22.8 for nonfiltered chlorinated water (7).

Chlorination of Anjou pear dump-water is very effective in preventing decay by *M. piriformis* (1). In our trial, chlorine appeared beneficial because it allowed an average of only 12.8 propagules/ml to survive. Prior to adding chlorine to the water it contained 43.0 ± 20.0 propagules/ml and when the average number of propagules was compared to values found in previous years the values were much lower in chlorinated water (Table 1). Although several bins of fruit were immersed in the dump-tank the number of propagules changed very little from day to day ranging from 0 to 27 propagules/ml (Table 2). This small number would not likely cause significant infection under commercial conditions as Spotts (9) showed that 25 spores/ml corresponds to 1.25% infection on wounded pears. Under commercial conditions it was estimated that approximately 5% of the pears would be wounded and only 73.5% of the propagules would be pathogenic, making it unlikely that significant decay would occur unless a higher number of propagules were present in the water. Furthermore, as shown in Table 2, decay by *Penicillium* was kept under control because the number of propagules of *Penicillium* spp. never rose above 166 ± 70 propagules/ml.

It is apparent from this study and those of others (1,10) that addition of 50-100 µg/ml chlorine to the dump-water is effective in destroying *Mucor* spp. propagules. It should be noted, however, that this is somewhat dependent on the floatation salt used. Spotts and Cervantes (12) found that when sodium sulfate at pH 7.8 was compared with sodium silicate at pH 11.2 in chlorinated water, the sodium sulfate water inhibited germination to a greater extent.

Table 2. Number of propagules/ml of *Mucor* spp. and *Penicillium* spp. in Anjou pear dump-water chlorinated with 50-100 µg/ml chlorine for 4 days

Day	Total Bins	Free Chlorine µg/ml	pH	Propagules/ml* *Mucor* spp.	*Penicillium* spp.
1	23	75	7.9	0±0	0±0
2	181	90	7.8	12±16	45±40
3	338	100	7.6	27±47	20±11
4	497	100	7.6	12±14	166±70

* Prior to adding sodium hypochlorite to the immersion water it contained 43.0 ± 20.0 *Mucor* spp. propagules/ml because the water was previously used for floating apples out of bins.

This study showed that propagules of *M. piriformis* occurred in sufficient numbers to cause pear decay at a commercial packinghouse in British Columbia. In order to reduce *Mucor* rot and avoid the costly inconvenience of repacking, packinghouse managers should use a sanitizing agent such as 50-100 µg/ml chlorine in the dump-tank. In addition, the dump tank should be emptied and thoroughly cleaned whenever the water becomes dirty. Spotts (9) found that using a spray rinse with clean water after the pears had been contaminated with spores reduced decay caused by *Botrytis cinerea, Penicillium expansum* and *M. piriformis*. This could be accomplished in the packinghouse by adding a spray nozzle above the pears as they come out of the dump-tank. Orchardists should be encouraged to place harvest bins on wood chips or some surface which prevents direct contact with soil, and fruit should never be removed from the ground and placed in the harvest bin. Fruit on the orchard floor should be removed and kept separate from fruit for packing.

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