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COMPARATIVE ACTIVITY OF SELECTED FOOD PRESERVATIVES AS CITRUS POSTHARVEST FUNGICIDES

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Abstract. Recently the food preservative potassium sorbate (KSrb) has been proposed as a postharvest fungicide for control of green mold (*Penicillium digitatum* (Sacc.)) on citrus. Two other food preservatives, sodium benzoate (NaBz) and sodium propionate (NaPr), are also used for similar food preservative applications. Trials on Valencia oranges inoculated with green mold indicate that all 3 have similar fungicidal activity and are equivalent to the traditional Dow-Hex treatment as a postharvest fungicide for citrus. None of these 3 chemicals are currently approved by the U.S. Environmental Protection Agency for postharvest use on citrus.

There are several fungicides that are currently approved for postharvest use on citrus; these include sodium o-phenylphenate (SOPP), thiabendazole (TBZ), benomyl, imazalil, and biphenyl (3, 6, 7, 8, 17). The occurrence of resistance to many of these (15) and the desirability of having alternative fungicides (2, 10) has led to the investigation of alternate materials. One of these is the common food preservative potassium sorbate (KSrb) (16, 21, 22).

Potassium sorbate has been investigated extensively for use on citrus with generally good results (16, 21, 22), while little value was found for its use on bell peppers (20).

Two other common food preservatives, sodium benzoate (NaBz) and sodium propionate (NaPr), have been used in similar food preservative applications but have not been reported as potential postharvest fungicides for citrus. Of the 3, NaPr has received the most attention for the control of fungi in food, while NaBz has been used for control of bacteria and KSrb for control of yeasts (4). Some of their properties are summarized in Table 1.

In a series of tests these 3 food preservative chemicals were compared for postharvest fungicidal activity against thiabendazole (TBZ) and sodium o-phenylphenate (SOPP) on Valencia oranges inoculated with citrus green mold (*Penicillium digitatum*).

The fungicide sodium o-phenylphenate (SOPP) is applied to citrus in several different formulations. One of these, 2% SOPP tetrahydrate with 1% hexamethylene tetramine (Dow-Hex), adjusted to pH 11.8 to 12.0, applied for 2 min at ambient temperature, is a standard for the Florida citrus industry (11, 12, 13, 14, 19). Another standard treatment is TBZ, which is often applied as a suspension at 1000 ppm a.i. with a wetting agent (6, 7, 18).

Materials and Methods

In each of 3 trials 30 Valencia oranges were inoculated with *P. digitatum* spores by puncturing each fruit 4 times on a conical point approximately 3 mm high by 3 mm at the base. Punctures were spaced around each fruit with a minimum of 2 inches between punctures. The fruit were then immersed in a suspension of spores harvested from previously inoculated untreated fruit. A sample from each spore suspension was challenged for benzimidazole resistance by testing for growth on potato dextrose agar modified with 20 ppm thiabendazole. The suspensions used in each trial were found to be benzimidazole sensitive.

The fruit were then held for 20 hours at ambient temperature before treating. After incubation the fruit were randomized into 6 lots of 5 fruit each. The lots were then treated as follows:

1. Control. No treatment.

2. TBZ. Fruit immersed 30 sec in a suspension of TBZ at 1000 ppm a.i. with 0.05% Triton X-100 as a wetting agent. Fruit were not rinsed following treatment.

3. Dow-Hex. Standard Florida treatment, 2% sodium o-phenylphenate with 1% hexamine, pH 11.9. Immersed 2 min. Rinse 30 sec. No added wetting agent.

4. Potassium sorbate. Immersed 2 min in 2% solution with 0.05% Triton X-100 as a wetting agent, pH 7.0-7.5. Rinse 30 sec.

5. Sodium propionate. Immersed 2 min in 2% solution with 0.05% Triton X-100 as a wetting agent, pH 7.0-7.5. Rinse 30 sec.

6. Sodium benzoate. Immersed 2 min in 2% solution with 0.05% Triton X-100 as a wetting agent, pH 7.0-7.5. Rinse 30 sec.

All treatments were performed at ambient temperature. The wetting agent, Triton X-100, is a non-ionic surfactant (9 mole ethoxylated octylphenol) produced by Rohm and Haas Co., Philadelphia, PA. The Dow-Hex solution was prepared from a commercial concentrate (Fresh Flood DX, Fresh Mark Corp., Ocoee, FL).

Each treated fruit was then placed on a sterile Kraft-paper surface and positioned so that the inoculation points were not in contact with any other fruit or the paper covered surface. The fruit were then held at ambient conditions (Approximately 70° F and 40% Relative Humidity) until examined.

After 144 hrs. the fruit were examined for decay at each inoculation point. Each inoculation point was also rated as to the presence of surface mycelia and spores. The results are summarized in Table 2. No decay occurred at any point other than at the inoculation points.

Results and Discussion

All of the treatments acted to reduce decay. Decay control by Dow-Hex and NaBz was better than the other treatments. While decay control by TBZ was less than the other treatments, it was not significantly less than the others.

Table 2. Decay, mycelial growth, and sporulation in inoculated Valencia oranges.

Treatment	No. inoc. ^y	Results ^z		
		% Decay ^x	% Mycelia ^w	% Spores ^v
Control	60	100.0 a	88.3 a	71.7 a
Dow Hex	60	20.0 b	6.7 b	1.7 b
Thiabendazole	60	55.0 c	15.0 c	11.7 c
Potassium sorbate	60	38.3 c	20.0 c	11.7 c
Sodium propionate	60	48.3 c	28.3 c	15.0 c
Sodium benzoate	60	30.0 bc	16.7 c	1.7 b

^zAverage of three replications. Means in same column followed by the same letter are not significantly different at the 95% level.

^yNumber of inoculation points, total at 4 per fruit.

^xPercent inoculation points showing decay, includes all stages of decay.

^wDecay has progressed to point of mycelia on surface of fruit, includes sporulating.

^vSpores visible to the unaided eye on the surface of the mycelia.

Table 1. Selected properties of potassium sorbate, sodium benzoate and sodium propionate.

Compound	CAS No. ^z	EPA code ^y	Formula	Mol. wt ^x	Activity ^w	
					Primary	Secondary
Potassium sorbate	246343-61-5	75902	C ₆ H ₇ KO ₂	150.22	yeasts	molds
Sodium propionate	137-40-6	77703	C ₃ H ₅ NaO ₂	96.07	molds	bacteria
Sodium benzoate	532-32-1	9103	C ₇ H ₅ NaO ₂	144.11	bacteria	yeasts

The high levels of decay in all treatments may be due to excessively severe injury in the inoculation procedure. This is borne out by the 100% decay in the controls.

The trials with the food preservatives were all carried out at pH of 7.0-7.5. Published information indicated that the acid form of these chemicals is more effective (4). Also, in food applications these chemicals are normally used at 100 to 1000 ppm while these trials were conducted at 2%. This difference may have accounted for some of the effectiveness found.

Since green mold (*P. digitatum*) infects fruit mainly by means of spores entering at points of injury (5) the extent to which an infection has developed towards sporulation is significant. Therefore any treatment that retards the progress of an infection towards sporulation would have some superiority over a treatment that has equal decay control but allows those decays that do develop to sporulate (10).

As indicated in Table 2 Dow-Hex, KSrb, NaPr and NaBz all acted to control sporulation by controlling decay. To the extent that decay was reduced sporulation was reduced. In this respect both SOPP and NaBz were better than the other treatments. Only TBZ reduced sporulation proportionally more than it reduced decay. The efficacy of SOPP at 2% as compared to potassium sorbate at 2% was greater which is contrary to an earlier report by Kitagawa and Kawada (16). This may be due to their having used SOPP at pH 12.5 which is too high for maximum efficacy (11, 12, 13).

Potassium sorbate has been shown to have slightly greater efficacy when used in heated solutions as compared to ambient (22). These trials were conducted at ambient as this has been demonstrated to be optimum for SOPP and any fungicide that might replace it would have to be clearly superior at another temperature in order to justify the expense of adding the equipment to apply at conditions other than ambient.

Regulatory status. Any chemical used commercially to control decay would come under the authority of the U.S. Environmental Protection Agency (EPA) and would require the registration of an End Use product containing it as the active ingredient. The 3 food preservatives, KSrb, NaPr and NaBz, used in these trials are all considered "safe" and are exempt from the requirement of a tolerance (1). This does not mean, however, that they are exempt from registration requirements (1, 9).

A search of the National Pesticide Information Retrieval System (NPIRS) using the chemical name, the EPA (Shaughnessy) code and the CAS No. for these salts and their acids found a total of 46 EPA registered products containing one or more of these as an active ingredient. These uses are summarized in Table 3. As can be seen from the table, neither sorbic acid nor potassium sorbate are registered for any pesticide applications in the U.S. Both benzoic and propionic acids and their sodium salts are in products registered with the EPA but none are for postharvest use on any products for human food use.

From these trials any of the chemicals tested have potential as a postharvest fungicide to control green mold on citrus. The effects of pH, time, temperature and application method still need to be more thoroughly investigated as well as their effect upon other decay organisms of commercial importance. Should any of these prove worthwhile, their use in the United States would still need government

Table 3. EPA registered uses for food preservative salts and their acids.²

Chemical	No. prods. reg. ³	Registered uses
Sodium benzoate	3	Mosquito repellent coils
Sodium benzoate	1	Fungicide/bactericide in shellfish processing
Benzoic acid	6	Mosquito repellent coils
Benzoic acid	2	Premises disinfectant, human & animal
Benzoic acid	1*	Stored grain fungicide
Propionic acid	27	Stored grain and fodder fungicide
Propionic acid	2	Manufacturing intermediate
Propionic acid	2	Ornamental plants and vegetable soil fungicide
Propionic acid	2	Bactericide in secondary oil recovery
Propionic acid	1	Hard surface mildew control
Sodium propionate	1	Manufacturing intermediate

²NPIRS. National Pesticide Information Retrieval System. On-line data base of pesticide products registered with the United States Environmental Protection Agency. Updated every 10 working days. Maintained by Purdue University, West Lafayette, IN.

³Number of different products registered with the U.S. EPA.

*One product also contains propionic acid.

approval which might prove too costly for any private company to justify.

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