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USE OF POSTHARVEST TREATMENTS FOR REDUCING SHIPPING DECAY IN KUMQUATS

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Abstract. **Mature kumquats are subject to some of the same postharvest diseases as citrus. Since the kumquat is a near relative (genus *Fortunella*) of the citrus (genus *Citrus*) the similarities in the fruit suggest that it would react to postharvest treatments in a similar manner. Treatments tested were chlorine, sodium o-phenylphenate (SOPP), thiabendazole (TBZ), 2,4-dichlorophenoxyacetic acid (2,4-D), and waxes. All treatments except 2,4-D alone improved resistance to decay, while a combination of SOPP and TBZ with a wax gave the best results. At the level tested 2,4-D had little apparent effect.**

The kumquat (genus *Fortunella*) is subject to losses from postharvest decay during shipment. Due to its popularity with some ethnic groups it commands a high price on the market and is usually shipped in small packages. Kumquat production in Florida is a small volume operation, amounting to only about 10,000 bushels before the 1984 & 1985 freezes greatly reduced the amount of fruit available (F. Gude, Kumquat Growers, Inc., personal communication). A true citrus, the kumquat fruit is small in size, typically 3/4 to 1 1/4 inches diameter (26). Depending upon variety, the fruit will be round to elongated in shape (8,26,27). The fruit are used for decoration in gift packs (26) and for use in various jams and preserves (22,23). They are also eaten fresh, peel included (8,19,26).

Relatively large quantities of the fresh fruit were shipped to markets in Los Angeles and San Francisco, California, Chicago, Illinois, and New York (F. Gude, personal communication). The large population of orientals in these cities probably accounts for this market. The kumquat probably originated in China and is still popular in most of the orient as a fresh fruit (8,25,26,27).

Eaten fresh, the kumquat has a peculiar sweetness not like that of other citrus. The peel has been found to contain dihydrochalcone flavonoids (10,13,14) similar to those recently developed as artificial sweetening agents (11,12,15). Differences in the oil of *Fortunella* (kumquat) as compared to *Citrus* have also been noted (17). Another notable difference between the kumquat and other members of the citrus family is its resistance to sour orange scab (20).

Before restrictions were placed upon fruit handling due to the outbreak of citrus canker in Florida (16), the fruit was clipped from the tree and packed loose into cartons or berry baskets for shipment to out of state markets. In addition, a considerable amount of fruit was harvested by clipping a small branch with several leaves and 3 or 4 fruit attached. These were used for decoration in gift boxes. Since canker quarantine restrictions require that all leaves and stems longer than 1 inch be removed from the fruit before shipping, this latter use has been discontinued.

Before canker quarantine restrictions were put into effect, whole fruit were clipped from the tree and packed into shipping containers with a minimum of handling. The restrictions require a chemical treatment (either chlorine or sodium o-phenylphenate (SOPP)) be given the fruit before packing (16). One Florida packer noted that since they began using a chlorine treatment in order to meet the quarantine requirements they have experienced increased decay in shipments (F. Gude, personal communication).

Their method of treatment was to dump the harvested fruit into a large wire basket (approximately 3 bushel capacity) which was lowered into a chlorine solution for 2 minutes. This basket of fruit was was then transferred to another tank containing fresh water to rinse, then the fruit was dumped upon a perforated metal table to drain before packing. This extra handling apparently was causing injury to the fruit making it susceptible to decay (2). Also contributing to injury was the requirement that all leaves and excess stem be removed. Picking thus, pickers tended to include more pulled or plugged fruit.

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The choices of postharvest treatments for kumquats are the same as those for citrus (5,18) as far as US Government regulations are concerned (1). In spite of this, since the kumquat has many differences in composition and reaction to disease as noted above, confirmation of the efficacy of any particular treatment would be in order. Because of the relatively small quantity of fruit involved and the short season, methods of treatment were sought that would be compatible with the equipment available and current regulations. All tests were conducted at the packinghouse and used the equipment available or scaled down versions of this equipment. In place of the wire baskets, plastic baskets were used.

Materials and Methods

Except as noted, all materials used in these trials were commercially available products. The test materials and treatments used were:

Chlorine. Commercial sodium hypochlorite supplied at 10% strength as used by the packinghouse. Product diluted to produce a dipping solution with 200-250 ppm chlorine at a pH of 6.0 to 7.5. Exposure time 2 min followed by fresh water rinse. Treatment indicated by the abbreviation CL_2 in the tables. Currently used at packinghouse to meet quarantine requirements (16).

SOPP. Traditional "Dow-Hex" solution (9,18) containing 2% sodium *o*-phenylphenate tetrahydrate and 1% hexamethylenetetramine at pH 11.6 to 12.0. Prepared from concentrate (Fresh Flood DX). Exposure time 2 minutes followed by fresh water rinse. As normally used, it would meet the requirements of citrus canker quarantine (16).

TBZ. Thiabendazole. Prepared from concentrate (Fresh Ban Z). Used at 1000 ppm active ingredient (a.i.) in water or 1000 or 2000 ppm a.i. in dilute wax. Dip for 30 seconds, no rinse. Does not meet quarantine requirements by itself, but is compatible with other possible treatments. Concentration indicated by TBZ(I) for 1000 ppm and TBZ(II) for 2000 ppm. Benomyl was discarded as a possible treatment as packinghouse conditions would not have resulted in prompt use of prepared fungicide. Such conditions would have resulted in breakdown of the fungicide (6).

Wax P. Emulsion type wax (7) containing high percentage of oxidized polyethylene solids (Fresh Wax 625). Used at 5, 2, and 1% calculated solids content. Fruit dipped for 30 seconds then drained, no rinse, both with and without fungicides. 5% solids wax indicated in tables by Wax P_5.

Wax D. Developmental storage wax provided by Fresh Mark. Emulsion type wax containing high percentage of true waxes, similar to storage waxes used for lemons in California (7). Used at 2% and 1% calculated solids content. Applied in the same way as Wax P and solids concentration indicated in the same way.

2,4-D. 2,4-dichlorophenoxyacetic acid, triethanolamine salt (Fresh Shield D). Used at 250 ppm acid basis. Chosen for simplicity of application and its usefulness against stem-end rot (2). Applied in combination with wax or fungicide.

Biphenyl. Biphenyl (diphenyl) impregnated kraft paper. Chosen for inclusion in these trials because of the simplicity of application (2,18) and low toxicity (24). Standard dosage is one or two sheets of biphenyl paper per 40 pound carton of fruit (18). One standard package used for kumquats contains 10 pounds of fruit. This size carton was used, with 1/4 of a standard sheet of biphenyl paper, for the biphenyl treated treatment in these trials. In order to get a more thorough distribution of this vapor phase fungistat throughout the carton each quarter sheet was further quartered for packing among the fruit. Its use in a treatment is indicated in the tables by Biph.

In each trial fruit was taken as it arrived at the packinghouse in Dade City, Florida. Each sample of the incoming fruit was divided into lots of about 3 quarts each (4 to 5 lbs.) (except as noted for biphenyl treatments) then given the treatments or combinations of treatments as indicated in Table 1. In the table the abbreviations above are used with "Check" indicating no treatment. Where treatments are separated by a slash (e.g., SOPP/TBZ(I)) one treatment followed another (fruit first treated with Dow-Hex for 2 minutes, rinsed, then treated with 1000 ppm TBZ). Treatments separated by "+" are combined (wax P_2+TBZ(II) indicates 2% solids Wax P applied with 2000 ppm TBZ incorporated in the wax). Biphenyl was always incorporated in with the packed fruit.

Trial #1 (10 treatments)

Initiated 11 Nov. 1985. Check indicates that only fresh water was used as a dip for 2 minutes. Fruit were then packed in 1/5 bushel boxes and stored for 7 days at 58°F and 85% relative humidity. The fruit was then transferred to ambient temperature for 17 days and examined for

Table 1. Treatments used in kumquat trials.

Treatment	Trial 1	Trial 2	Trial 3
1.	Check	Cl_2—Only[z]	Cl_2—Only[z]
2.	Cl_2—Only	SOPP	TBZ(I)
3.	TBZ(I)	SOPP/Wax P_1	TBZ(I) + 2,4-D
4.	SOPP	SOPP/Wax D_1	TBZ(II) + Wax P_2
5.	Cl_2/SOPP/TBZ(I)	SOPP/TBZ(I)	TBZ(II) + Wax D_2
6.	Cl_2/SOPP/TBZ(I)	SOPP/TBX(II) + Wax P_1	TBZ(II(+ Wax P_2 + 2,4-D
7.	SOPP/TBZ(I)	SOPP/TBZ(II) + Wax D_1	TBZ(II) +Wax D_2 + 2,4-D
8.	SOOP/TBZ(I) + Wax P_5	TBZ(I)	TBZ(II) + Wax P_2 + 2,4-D & Biph.
9.	Cl_2/TBZ(I) + Wax P_5	TBZ(II) + Wax P_1	TBZ(II) + Wax D_2 + 2,4-D &Biph.
10.	Cl_2/SOPP/Wax P_5	TBZ(II) + Wax D_1	TBZ(II) + 2,4-D & Biph.
11.		Biph.	
12.		TBZ(II) + Wax P_1 & Biph.	
13.		TBZ(II) + Wax D_2 & Biph.	

[z]All treatments in these trials were treated first with chlorine. See text.

decay, soilage and marketable fruit (Table 2). The SOPP treatment was chosen because it also meets the requirements of quarantine (16) and could replace the chlorine if desired. The TBZ(I) treatment would be simple to implement; while not meeting requirements of quarantine it is approved for use on kumquats and is similar to processes already used (1,7). With the exception of treatments 1 and 3, all treatments in this trial would meet the requirements of the canker quarantine (16).

Trial #2 (13 treatments)

Initiated 4 Dec. 1985. Fruit were treated as indicated in Table 1, packed in 1/5 bushel boxes and stored for 12 days at ambient temperature, then examined for decay, soilage and marketable fruit. When applied in wax it has been recommended that the concentration of most fungicides be doubled when compared with a water based application (3,7). In trial TBZ was used at 2000 ppm when used applied in a wax and at 1000 ppm when applied in a water carrier. Treatments using biphenyl as described above, were included in this trial. The results are reported in Table 3.

Trial #3 (10 treatments)

Initiated 19 Jan. 1986. Fruit were treated as indicated in Table 1, then packed in 1/5 bushel boxes and stored for 25 days at ambient temperature, then examined for decay, soilage and marketable fruit. This trial included 2,4-D in several treatments because of its reported ability to reduce mold in products packed with stems and leaves (21) in addition to its usefulness against stem-end rot (2). (Table 4). The longer storage time was due to lower ambient temperatures during Jan-Feb 1986.

Results and Discussion

In Trial #1 (Table 2), early season fruit, chlorine was found to have a definite effect on reducing the amount of decay. This probably was due to simply reducing the inoculum present on the fruit. Upon the conclusion of this trial, the fruit was examined for decay and soiling and the clean, sound fruit were counted as marketable. On this test all treatments markedly reduced decay, the best control being those treatments involving TBZ. In the check lot green mold (*Penicillium digitatum* Sacc.), was a major cause for fruit loss due to decay and soiled fruit. Besides green mold, sour rot (*Geotrichum candidum* Lk. ex pers.) and stem end rot (*Diplodia natalensis* Pole Evans) were identified (4). The stem end rot did not follow the normal course of development for diplodia (decay from both end) but presented itself as a clearing of the fruit from the stem end. The typical darkening of tissues as usually noted in *Citrus* was absent.

Table 2. Results of Trial 1.

Treatment	Total fruit	Decay			Marketability	
		Green mold	Other[z]	Soiled	Total	%
1. Check	190	10	30	46	104	54.7 a[y]
2. Cl_2—Only	142	1	22	12	107	75.4 b
3. TBZ(1)	132	0	1	1	131	99.2 de
4. SOPP	141	4	10	23	104	73.8 b
5. Cl_2/SOPP	126	0	10	2	114	90.5 cd
6. Cl_2/SOPP/TBZ(1)	146	0	1	0	145	99.3 de
7. SOPP/TBZ(1)	162	0	1	0	161	99.4 de
8. SOPP/TBZ(1) + Wax P_5	145	0	0	0	145	100.0 e
9. Cl_2/TBZ(1) + Wax P_5	170	0	32	0	138	81.1 bc
10. Cl_2/SOPP/Wax P_5	158	9	19	21	109	69.0 b

[z]Stem end, sour and other rots.
[y]Values not followed by the same letter differ significantly at the 5% level of confidence.

Table 3. Results of Trial 2.

Treatment	Total fruit	Decay			Marketability	
		Green mold	Other[z]	Soiled	Total	%
1. Cl_2[y]	166	15	28	38	85	51.2 a[x]
2. SOPP	183	6	34	18	125	68.3 d
3. SOPP/Wax P_1	190	12	71	27	80	42.1 c
4. SOPP/Wax D_1	178	9	44	20	105	59.0 b
5. SOPP/TBZ(I)	177	1	21	6	149	84.2 g
6. SOPP/TBZ(II) + Wax P_1	171	0	20	0	151	88.3 g
7. SOPP/TBZ(II) + Wax D_1	173	0	20	0	153	88.4 g
8. TBZ(I)	202	0	47	0	155	76.7 ef
9. TBZ(II) + Wax P_1	201	1	33	0	147	73.1 de
10. TBZ(II) + Wax D_1	233	0	44	0	189	81.1 ef
11. Biph.	393	27	51	84	231	58.8 ab
12. TBZ(II) + Wax P_1 & Biph.	371	0	55	0	316	85.2 g
13. TBZ(II) + Wax D_1 & Biph.	374	1	42	0	331	88.5 g

[z]Stem end, sour and other rots.
[y]All treatments in this trial received chlorine before all other treatments. See text.
[x]Values not followed by the same letter differ significantly at the 5% level of confidence.

Table 4. Results of Trial 3.

Treatment	Total fruit	Decay			Soft[y]	Marketability	
		Green mold	Other[z]	Soiled		Total	%
1. Cl_2—Only[x]	242	45	57	102	16	22	9.1 a[w]
2. TBZ(1)	231	1	11	0	31	188	81.3 d
3. TBZ(I) + 2,4-D	219	1	34	0	25	159	72.6 b
4. TBZ(II) + Wax P_2	230	0	27	0	28	175	76.1 c
5. TBZ(II) + Wax D_2	234	0	21	0	22	191	81.6 e
6. TBZ(II) + Wax P_2 + 2,4-D	236	1	24	0	21	190	80.5 de
7. TBZ(II) + Wax D_2 + 2,4-D	251	0	23	0	13	215	85.7 f
8. TBZ(II) + Wax P_2 + 2,4-D & Biph.	433	0	70	0	16	347	80.1 d
9. TBZ(II) + Wax D_2 + 2,4-D & Biph	429	0	40	0	21	364	82.9 e
10. TBZ(1) + 2,4-D & Biph.	493	0	46	8	19	368	85.8 f

[z]Stem end, sour and other rots.
[y]Fruit too soft to be acceptable as fresh. See text.
[x]All treatments in this trial were treated first with chlorine.
[w]Values not followed by the same letter differ significantly at the 5% level of confidence.

Not included in the rating for marketability were two factors that could affect the acceptability of the fruit to consumers. In this trial, the waxed fruit all had a very pleasing shine but were all objectionably sticky to the touch which would detract from their acceptability. All treatments involving chlorine also were noted to have a much brighter appearance, probably due to the bleaching effect of the treatment.

Trial #2 was examined and rated in the same manner as Trial #1. Since all treatments started with a chlorine treatment no difference in brightness of the fruit was noted. Again, all treatments using TBZ gave good control. When biphenyl was added a very slight improvement was noted. Waxing seemed to reduce the effectiveness of an SOPP treatment but not a TBZ treatment. Wax P and Wax D were both used at the 1% level and did not give any objectional feel to the fruit. Wax P gave a slightly improved appearance as compared to the other treatments including Wax D.

Trial #3 involved fruit from late in the season, as a consequence a large number of fruit past the peak of maturity were included. This fruit was also more susceptible to plugging at the time of picking. Plugging and other injuries are apparently the cause of the high amount of green mold found in the chlorine only treatment. The waxes used were applied at 2% solids and Wax P gave a very pleasing appearance without being sticky. Wax P seemed to interfere with the action of TBZ to a slightly greater extent than Wax D, but Wax D did not improve the appearance of the fruit. 2,4-D was included in several of the treatments but had only minor effect on decay control, as did biphenyl. A slight effect on reducing the amount of soft fruit was noted but not enough trials were run to reach any definite conclusion.

Included in the evaluation of this trial was a notation of a large number of soft fruit. These fruit had no visible external signs of decay but were too soft to be acceptable to a consumer expecting a normally firm, slightly crisp fruit. A few of these soft fruit were found to be decayed inside. It is interesting to note that in every treatment using biphenyl the proportion of soft fruit was less (approximately half) than in the other treatments. The quantity involved was not enough to draw any conclusions. Biphenyl has a distinct odor and there was concern that this could affect the flavor of the fruit. Informal trials by packinghouse personel that had acquired a taste for kumquats did not indicate that any objectional flavor had developed (F. Gude, personal communication).

These trials indicate that the fungicides SOPP and TBZ are both of value in controlling postharvest decay in kumquats. Chlorine followed by TBZ, with or without wax, is a simple procedure readily adaptable to the needs of a limited production situation. Superior appearance and decay control in plugged fruit would make this the process of choice.

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