mango anthracnose control with hot benomyl, hot prochloraz and hot water supports reports by others (2, 3, 6, 7, 8, 10, 11, 12, 14). However, none of the researchers reported injury with hot imazalil or hot prochloraz as was noted in this study. Injury with hot imazalil at 0.2% was very serious. However, in previous studies (13) hot imazalil at 0.1% controlled anthracnose without injury to the mangos. In spite of the use of several of these fungicides (3, 6, 7, 10, 14) further studies are necessary to answer the questions of disease control and fruit injury in relation to fungicide concentration and water temperature. These data are not to be construed as a postharvest mango anthracnose control recommendation until cleared for this purpose by State and Federal regulatory agencies.

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INFLUENCE OF HIGH-TEMPERATURE CONDITIONING ON PEEL INJURY AND DECAY OF WAXED OR FILM WRAPPED FLORIDA GRAPEFRUIT AFTER LOW-TEMPERATURE STORAGE[1]

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Additional index words. curing, chilling injury, *Citrus paradisi*, shipping, export, quarantine treatment.

Abstract. **Grapefruit (*Citrus paradisi* Macf.) waxed or film-wrapped were conditioned (CON) for 72 hr at 34°C, 95% RH (HiRH) or at 34°C, 30% RH (LoRH) or were nonconditioned (NONCON). Postcuring storage was 4 weeks at 10, 4 or 1°C for NONCON fruit and 4 or 1°C for CON fruit followed by 1 week at 21°C. CON fruit tended to have less chilling injury (CI) than NONCON fruit after 3 or 4 weeks' cold treatment at 4 or 1°C. NONCON fruit stored at 10°C generally had the least CI and NONCON stored at 1 and 4°C tended to have the most, compared to other treatments. There was no significant difference ($P < 0.05$) in CI for NONCON or CON (HiRH or LoRH) fruit held at 1 or 4°C, but after 3 or 4 weeks' storage, CON fruit tended to have less CI than similarly held NONCON fruit. CON fruit stored at 1°C had higher incidences of penicillium rot than those stored at 4°C or NONCON fruit stored at 10°C after the total 5 weeks' storage regime. CON fruit stored at 1 or 4°C were consistently less fresh (higher freshness index values) than NONCON fruit stored at 10, 4 or 1°C. Film wrapping reduced weight loss, maintained fruit freshness, reduced pitting, and reduced the development of penicillium rot compared to waxed fruit. Although conditioning tended to reduce CI compared to nonconditioning of fruit during low-temperature storage, the incidences of CI that developed were excessively high and did not significantly reduce decay development.**

Prolonged exposure of grapefruit to low-temperature postharvest storage usually results in chilling injury (CI) manifested as rind pitting or rind discoloration (scald). The principal objectives of developing methods to store grapefruit at low temperature are 1) prevent development of CI, 2) reduce decay (16), and 3) maintain fruit freshness and flavor. Mold rots caused by *Penicillium* spp. are the most prevalent postharvest decays of Florida citrus fruit (17). Recently, low-temperature treatments are replacing ethylene dibromide (EDB) for control of insect pests, such as the Caribbean fruit fly in postharvest storage. Alternative methods that provide successful quarantine treatments without causing CI are needed. Japan is a major importer of Florida grapefruit; 9.2 million boxes or 22% of Florida fresh market grapefruit for the 1986-1987 season. Most of the grapefruit exported to Japan from Florida will require

[1]Mention of a trademark, warranty, proprietary product, or vendor does not constitute a guarantee by the U.S. Department of Agriculture and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

cold treatment due to the banning of EDB as a quarantine treatment by the 1989-90 season.

Recent literature shows that chemicals (6, 11, 12, 15, 17), waxes or plastic wraps (2, 13, 14), and prestorage conditioning of fruit for various times and temperatures (4, 7, 8, 9) can significantly reduce the development of CI and/or decay. Ismail et al. (10) and Brown et al. (3) reported that rind wound healing was enhanced by high temperatures and high humidity, which led to inhibition of penicillium rots. Golomb et al. (5) and Ben-Yehoshua and coworkers (1) combined high-temperature conditioning with plastic film wrapping techniques and further defined optimal temperatures for conditioning, and demonstrated a reduction of mold rot decay in citrus fruit.

The purpose of this study was to determine the effects of high-temperature conditioning of film-wrapped or waxed grapefruit at low or high relative humidity (RH) on the subsequent development of CI and decay during relatively long-term storage at 4°C or the quarantine cold-treatment temperature of 1°C.

Methods

Grapefruit were commercially harvested in January, March, and April 1987, and each harvest (replication) was from a different grove. Fruit were selected from field bins at the packinghouse, graded and sized (8.9 to 10.6 cm diameter) by hand. At the laboratory, fruit were washed, regraded and coated with wax (Fresh Mart 1103) or plastic film (EHC 50, DuPont) but no fungicides were applied; then 15 fruit were placed into each of 14 standard-size 4/5 bushel, full-telescoping, corrugated fiberboard citrus boxes. Seven boxes contained waxed fruit and seven film-wrapped fruit. Fruit were then CON for 72 hr at 34°C at 30% RH ± 5% (LoRH) or 34°C, 95% RH ± 5% (HiRH) or were NONCON. NONCON fruit were held at 10°C, 90% RH ± 5%, during the 72-hr conditioning period. After the 72-hr conditioning period, CON fruit were stored at 1 or 4°C for 4 weeks, NONCON fruit were stored at 1, 4 or 10°C for 4 weeks. All fruit were held 1 additional week at 21°C (95% RH ± 5%) to simulate a short marketing period. NONCON fruit stored continuously at 10°C during 72-hr conditioning plus 4 weeks were considered the controls. These particular temperature and storage times were selected to simulate potential transit or storage temperature (10°, 4°C) or quarantine cold-treatment temperature (1°C) that might be used for grapefruit during shipping from Florida to Japan.

Fruit were weighed before and after the 72 hr conditioning period and at weekly intervals during storage. All fruit were inspected after the conditioning period and at biweekly intervals thereafter for symptoms of CI, decay, and freshness. CI symptoms of pitting or scald were scored separately but neither for degree of severity. Decay was categorized by type: 1) penicillium rot (PENROT), 2) stem end rots (SER) caused by *Diplodia* sp. or *Phomopsis* sp. at the caylx end, or 3) miscellaneous rots (MISC). The latter two rots (SER and MISC) were also combined and catagorized as other rots. Fruit were subjectively scored for three appearance characteristics: 1) rind appearance, i.e., brightness and gloss of surface color, 2) freshness of caylx or abscission scar, and 3) fruit turgidity. For each characteristic, a value of 1, 2, or 3 (good, fairly good, or poor, respectively) was given to fruit on a box-lot basis at each inspection. The three characteristic values were averaged, resulting in a single fruit appearance index (FAI) value representing degree of fruit freshness. Decay and CI were expressed as percentages of initial fruit affected and weight loss as percentage of cumulative decrease in weight during storage.

All data were averaged over the three replicate harvests and subjected to analysis of variance testing procedures.

Results

Chilling injury—pitting. Pitting was the most serious peel disorder observed. Conditioning or storage temperature did not significantly influence the incidence of pitting during storage at 1 or 4°C or after 1 additional week at 21°C. Pitting was significantly reduced by film wrapping, developing at about 1%/week compared with 6%/week for waxed fruit during 4 weeks' storage when averaged over all treatments (Table 1). After 1 additional week at 21°C, values for pitting were less accurate because some fruit previously pitted were now decayed, thus masking symptoms of pitting. Although not statistically different, there was a tendency for less pitting of CON LoRH fruit then CON HiRH or NONCON fruit during 1 or 4°C storage. Generally, less pitting was observed on NONCON fruit stored at 10°C than on NONCON fruit stored at 1 or 4°C (complete data not shown).

Scald. Scalding (stain) of fruit peel was observed only on fruit obtained in the second of the three tests March harvest). Relatively severe scald blotches developed after 3 weeks in storage but only on the surface of waxed, HiRH conditioned fruit. The percentage of fruit with scald in these particular treatments was 84% and 90% for fruit after 4 weeks' storage at 1 or 4°C, respectively. Apparently, fruit obtained for the second test was highly susceptible to either the conditioning treatment or low temperature. For these fruit, the combination of conditioning and/or storage at 1 or 4°C resulted in severe scald instead of the charac-

Table 1. Percentage of chilling injury (pitting) on nonconditioned (NONCON) or conditioned (CON)[z] film-wrapped (FL) or waxed (WX) grapefruit after 4 wk storage at 10, 4, or 1°C plus 1 wk at 21°C.

Treatment	Storage temperature (°C)	Coating	Wk of storage 1	2	3	4	5[y]
NONCON	10	FL, WX	0	2	3	4	6
NONCON	1, 4	FL, WX	1	7	17	23	22
CON (HiRH)	1, 4	FL, WX	3	7	11	14	14
CON (LoRH)	1, 4	FL, WX	1	2	6	9	12
		FL	1	2	4	5	9
		WX	1	8	16	23	20
Effects[x]							
Coating			NS	*	*	*	*
Treatment (1°, 4°)[w]			NS	NS	+	NS	NS
NONCON (1°, 4°, 10°)[v] (Data not shown)			NS	*	*	NS	**

[z]Prestorage conditioning for 72 hr at 34°C, 95% RH (CON HiRH) or 34°C at 30% RH (CON LoRH).
[y]Values after 1 wk at 21°C may be less accurate due to removal of pitted decayed fruit.
[x]Nonsignificant (NS), significant at the 5% (*) or 10% (+) level by factoral analysis using ANOVA procedures.
[w]Significant differences for NONCON, CON HiRH or CON LoRH stored at 1 and 4°C only.
[v]Effect for NONCON fruit stored at 10, 4 or 1°C only; values for NONCON fruit at 4 or 1°C not separately shown.

Table 2. Percentage of total decay, penicillium (PEN) or OTHER (SER and MISC) rots for grapefruit conditioned (CON) for 72 hr at 34°C at 95% RH HiRH or 30% RH LoRH or nonconditioned (NONCON) and stored 4 wk at 10, 4, or 1°C then held 1 wk at 21°C.

No.	Treatment	Storage temp (°C)	Storage time and type of decay: 4 wk storage Total	4 wk storage PEN	4 wk storage OTHER	+ 1 wk at 21°C Total	+ 1 wk at 21°C PEN	+ 1 wk at 21°C OTHER
1	NONCON (control)	10	11A[z]	4A	7A	38	7A	31
2	NONCON	4	2	1	1	26	8A	18
3	CON HiRH	4	3	0	3A	24	9A	15
4	CON LoRH	4	3	2	1	17	8A	9
5	NONCON	1	1	0	1	26	18A	8
6	CON HiRH	1	3	0	3A	46	34	12
7	CON LoRH	1	1	1	1	44	33	11
	Treatment 2, 3, 4	4	3	1	2	23	9	14
	Treatment 5, 6, 7	1	1	1	1	39	29	10
	Film	1, 4	2	1	1	16	6	11
	Wax	1, 4	2	1	1	45	31	14
Effects[y]								
Treatment			*	*	+	NS	*	NS
Storage temp (1°, 4°)[x]			NS	NS	NS	*	*	NS
Storage temp (°1, 4°, 10°)[w] (NONCON only)			*	*	+	NS	NS	+
Coat (1°, 4°)[x]			NS	NS	NS	*	*	NS
Coat by Storage temp (1°, 4°)[x]			NS	*	NS	*	*	+

[z]Values followed by higher case letter A are not significantly different from value for Treatment 1 (control) in this data set by Duncan's multiple range test at the 5% level of significance.
[y]Significant at 5% (*) or 10% (+) or nonsignificant (NS) by ANOVA factorial procedures.
[x]Effect of NONCON, CON HiRH or CON LoRH during 1 or 4°C storage on decay.
[w]Effect of NONCON only at 10, 4 or 1°C (Treatments 1, 2, 5) on decay.

teristic pitting usually observed at these storage temperatures for grapefruit. However, since the scald could not be positively identified as caused by CI alone, results for scald were not combined with pitting results, but provided separately.

Decay. Average total decay was 3 and 32% after 4 or 5 weeks' storage, respectively. NONCON fruit stored 4 weeks at 10°C (TRT 1) had 11% decay, which was significantly ($P < 0.05$) higher than decay levels of any other treatment (Table 2). Decay in all treatments increased after fruit were held 1 additional week at 21°C, and ranged from 17% for CON (LoRH) fruit stored at 4°C to 46% for CON (HiRH) fruit stored at 1°C. The lower temperatures (1°, 4°C) had a beneficial effect of reducing decay development for NONCON fruit only (TRT 1, 2, 5) after 4 weeks of storage, but this effect disappeared after fruit were held an additional week at 21°C. Fruit stored 4 weeks at 4°C plus 1 week at 21°C had much less PENROT and less total decay than similar fruit stored at 1°C. Film-wrapped fruit had less total decay (16%) compared with waxed fruit (45%) only after storage at 21°C, where PENROT was reduced fivefold by the plastic film wrap. Regardless of conditioning treatment, injury caused by 1°C storage apparently allowed green mold to develop when fruit were held at 21°C. Film wrapping apparently inhibited the movement of fungal spores among fruit, thus preventing infection of adjacent fruit and reducing secondary infection. More decay developed on fruit held at 10°C (TRT 1), generally, than in all other treatments after 4 weeks' storage. However, after 1 week at 21°C, those fruit previously exposed to 1°C for 4 weeks greatly increased in PENROT, compared to those fruit stored at 4 or 10°C.

SER and MISC rot were combined and given as 'OTHER' in Table 2. Phomopsis as SER was the most prevalent of these rots. SER and MISC rots developed slowly during 4 weeks' storage at 1 or 4°C, but tended to develop more rapidly in those fruit stored at 10°C. After 1 week at 21°C, NONCON fruit held continuously at 10°C tended to have higher amounts of OTHER rot than all other treatments. Type of fruit coating had no influence on development of OTHER rots.

Fruit appearance. NONCON fruit stored at 1 and 4°C or at 10°C had lower FAI values than CON fruit stored at 1 or 4°C (Table 3). The conditioning effect decreased freshness and was generally independent of the coating effect. Conversely, the effect of film wrapping to maintain freshness was independent of the conditioning effect. Film-wrapped fruit maintained higher levels of fruit freshness compared to waxed fruit. There was no difference in FAI values at the storage temperatures tested.

Table 3. Grapefruit appearance[z] index (FAI) values for nonconditioned (NONCON) or conditioned (CON) for 72 hr at 34°C at 95% RH HiRH or 30% RH LoRH and stored 4 wk at 10°, 4°, or 1°C, then held 1 wk at 21°C.

Treatment	Storage temperature (°C)	Coating	Storage (wk) 1	2	3	4	5 at 21°C
NONCON	10	FL, WX	1.9	2.0	2.1A	2.3	2.4
NONCON	1, 4	FL, WX	1.9	2.0	2.2A	2.3	2.4
CON HiRH	1, 4	FL, WX	2.2	2.2	2.4	2.5	2.6
CON LoRH	1, 4	FL, WX	2.4	2.4	2.5	2.5	2.6
		Film	1.9	2.0	2.1	2.2	2.3
		Wax	2.3	2.4	2.6	2.7	2.7
Effects[y]							
CON			*	*	*	*	*
Coat			*	*	*	*	*
CON by Coat			*	NS	*	*	NS

[z]Means of composite values based on rind freshness, calyx or button freshness and fruit firmness, i.e. 1 = fresh; 2 = fairly fresh; 3 = not fresh.
[y]Significant (*) or nonsignificant (NS) by ANOVA procedures at the 5% level.

Table 4. Percentage of cumulative weight loss for grapefruit nonconditioned (NONCON) or conditioned (CON) for 72 hr at 34°C at 95% RH HiRH or 30% RH LoRH and stored 4 wk at 10, 4, or 1°C.

Treatment	Storage temp (°C)	Coating	After 72 hr CON	Storage time (wk)			
				1	2	3	4
NONCON	10	FL, WX	0.7	0.7	1.0	1.1	1.3
NONCON	1, 4	FL, WX	0.3	0.5	0.6	0.8	1.0
CON HiRH	1, 4	FL, WX	0.3	0.7	0.8	0.9	1.0
CON LoRH	1, 4	FL, WX	2.1	2.8	2.8	3.3	3.4
		Film	0.3	0.3	0.4	0.5	0.5
		Wax	1.6	2.4	2.5	2.9	3.1
Effects[z]							
CON			*	*	*	*	*
Coat			*	*	*	*	*
CON by Coat			*	*	*	*	*

[z]Significant (*) by ANOVA factorial procedures at 5% level.

Weight loss. Weight of CON (LoRH) fruit decreased significantly more during the 72-hr conditioning period than CON (HiRH) or NONCON fruit (Table 4). The rate of weight loss was similar during 4 weeks of storage after conditioning among conditioning treatments, and was not dramatically influenced by storage temperature. Weight loss was significantly ($P < 0.05$) reduced by film wrapping during the conditioning period and subsequent storage for 4 weeks compared to waxed fruit. The effect of conditioning on weight loss was dependent on fruit coating (wax or film wrap) and conversely the effect of coating was dependent on conditioning.

Discussion

This study confirms findings of earlier work concerning relationships between storage temperature, CI, and decay. We verified with grapefruit that plastic film reduces CI, controls PENROT development, maintains fruit appearance and reduces moisture loss, compared to wax-coated fruit. Conclusions concerning the influence of high-temperature conditioning on fruit during storage, however, were less definitive. Conditioning (LoRH) tended to reduce CI compared to CON (HiRH) and NONCON fruit similarly held, but NONCON fruit held at 10°C had the lowest incidence of CI development. Conditioning and storage at 4°C did not affect PENROT development compared to nonconditioning, but conditioning and storage at 1°C increased PENROT development compared to nonconditioning after the 5-week storage regime.

Therefore, decay results do not indicate that high-temperature conditioning (34°C) for 72 hr will allow lowering storage temperatures to 1°C without substantial increases in levels of decay compared to NONCON fruit, and decay development of CON fruit after 4°C storage is similar to that of NONCON fruit. Perhaps different periods of conditioning time at high temperatures may be beneficial in reducing CI and decay during subsequent low-temperature storage. Conditioning of film-wrapped fruit, however, at low or high RH was less detrimental to fruit based on combined indicators of fruit condition, such as weight loss, fruit appearance, CI and decay levels compared to waxed fruit (data not shown). These findings agree with those of Ben-Yehoshua et al. (1), who reported that plastic film provided a barrier to moisture within its microatmosphere envelope sufficient to maintain fruit quality and enhance wound healing even at lower ambient RH conditions. In contrast, significant changes in the level of RH has a relatively large effect on the subsequent condition of waxed fruit. Finally, fruit in this study were intentionally not treated with fungicides, and we do not infer that similar differences in decay development would result in fruit treated with an effective fungicide.

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