

# Effects of Vegetable Oils, CO<sub>2</sub>, and Film Wrapping on Chilling Injury and Decay of Lemons

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*Additional index words.* *Citrus limon*, citrus, postharvest disorders, prestorage conditioning

**Abstract.** Film wrapping or holding for 3 days at 21°C reduced chilling injury (CI) and decay of 'Bearss' lemons (*Citrus limon* Burm. f.) stored at 1° for 21 days plus 14 days at 21°. Prestorage treatments of 40% CO<sub>2</sub> for 3 days at 21° or dips in 2%, 10%, or 20% vegetable oils were not effective in reducing CI or decay during a similar storage and holding period. The use of 10 µl·liter<sup>-1</sup> ethylene to degreen lemons significantly increased CI and decay compared to degreening without ethylene, especially when lemons were stored at 1°.

Ethylene dibromide (EDB) currently is used as a postharvest fumigant for Florida citrus fruits exported to Japan to protect against the spread of Caribbean fruit fly, *Anastrepha suspensa* (Loew). Withdrawal of registration for the use of EDB for fumigation of domestically consumed fruits in 1984 (14) and its possible elimination for treating exported fruits, has led to the search for alternatives, such as low-temperature storage. The USDA has authorized the use of low storage temperatures as a quarantine treatment against certain fruit fly pests (13). However, citrus fruits, particularly grapefruit and lemon, are susceptible to CI when exposed to temperatures below 10°C for more than 14 to 21 days (4, 8).

Recently, several treatments that reduce the susceptibility of citrus fruits to CI during storage have been reported. These include prestorage treatment of 40% CO<sub>2</sub> (5), film wrapping (9, 15), coating fruit surfaces with vegetable oils (1), use of the fungicide thiazobenzazole (TBZ) (10, 15), and conditioning at high temperatures prior to low-temperature storage (3, 6, 7).

Although conditioning at high temperatures has been effective in reducing CI with other types of citrus, holding lemons at 15.5°C prior to low-temperature storage did not reduce CI (8). However, since treatments other than conditioning at high temperatures have been effective in reducing CI, it may be pos-

sible that their use as adjuncts to conditioning would mitigate the effects of subsequent low-temperature storage on the development of CI.

The purpose of this study was to evaluate various treatments in combination with the normal degreening process (0 µl·liter<sup>-1</sup> ethylene) and also with ethylene degreening (10 µl·liter<sup>-1</sup>) at 15.5°C, followed by a low-temperature storage period necessary to qualify as a quarantine treatment against the Caribbean fruit fly.

'Bearss' lemons were obtained from a commercial packinghouse from different groves 3 times between 9 Aug. and 20 Sept. 1984. On each occasion, fruit were harvested commercially the previous day into bulk field bins, transported to the packinghouse, and left overnight. Fruit, free of blemishes and green in color, were hand-sized into a count range of 140-200 and transported to the U.S. Horticultural Research Laboratory in Orlando. All fruit were dipped for 30 sec in 600 µg·liter<sup>-1</sup> benomyl. Lemons from each harvest were degreened without added ethylene at 15.5°C and at 80% to 92% RH, and similar samples were degreened with 10 µl·liter<sup>-1</sup> ethylene. The time of degreening averaged 36 days without added ethylene and 4 days with 10 µl·liter<sup>-1</sup> ethylene. When the lemons in individual treat-

ments were sufficiently yellow in color, they were washed and drenched with 600 µg·liter<sup>-1</sup> benomyl and subjected to the following treatments: 1) a 30-sec dip in 2%, 10%, or 20% safflower oil in water emulsion with 0.2% Tween 80 surfactant; 2) an oil control, a 30-sec dip in water with 0.2% Tween 80; 3) a water control, a 30-sec dip in water; 4) CO<sub>2</sub> plus wax, 3 days in 40% CO<sub>2</sub> at 21°; 5) a CO<sub>2</sub> control, waxed, 3 days in normal atmosphere at 21°; 6) film wrap, sealed in Cryovac D955 film (W.R. Grace, Duncan, S.C.) with a Weldomatic sealer and Weldomatic heat tunnel (Weldotron, Piscataway, N.J.); and 7) film control, waxed only. CO<sub>2</sub> treated, CO<sub>2</sub> control, and film control fruit were waxed with Fresh Wax 3202 (Fresh Mark Chemical, Orlando, Fla.), a water-type wax, before the respective treatments.

In each of 3 different tests (harvests), 4 replications of 25 fruit per treatment were held in separate storage containers. The fruit then were stored for 21 days at either 1° or 10°C under a RH of 80% to 92%.

Fruit were inspected on removal from storage and after 7 and 14 days at 21°C and 88% to 92% RH. CI was classified as either rind pitting or brown staining and tabulated quantitatively. Decayed fruit were counted and classified according to types of decay and discarded at each inspection. For presentation, the quantitative data for each of CI and decayed fruit were combined into single numerical percentage values.

The percentages of CI and decay increased by storage at 1°C compared to 10° and by degreening with 10 µl·liter<sup>-1</sup> ethylene compared to degreening without ethylene (Tables 1 and 2). Also, there was a significant interaction between storage temperature and method of degreening on CI development after storage and holding at 21°C, where the effect seemed to be synergistic. The same interaction was significant for decay only after 14 days of holding at 21°. Previous work by me showed that the use of 1 µl·liter<sup>-1</sup> ethylene for degreening had no significant effect on CI and decay development (8). Barmore et al. (2) found that a fungicide application both before and after degreening with 1-10 µl·liter<sup>-1</sup> ethylene adequately controlled decay in Florida lemons. Results of this study are compatible with those of Barmore et al. (2) for lemons stored at 10° but not at 1°, where excessive CI and decay

Table 1. F value significance for effects of storage temperature, method of degreening, and prestorage treatments on chilling injury and decay development in lemons.

Effect	Significance level					
	Chilling injury			Decay		
	After 21 days of storage	After holding at 21°C		After 21 days of storage	After holding at 21°	
	7 days	14 days		7 days	14 days	
Temperature (TE)	***	***	***	*	***	***
Ethylene (C <sub>2</sub> H <sub>4</sub> )	***	***	***	NS	NS	***
Treatments (TR)	NS	*	**	NS	**	***
TE × C <sub>2</sub> H <sub>4</sub>	***	***	***	NS	NS	***
TE × TR	*	**	**	NS	**	**
C <sub>2</sub> H <sub>4</sub> × TR	*	*	*	NS	NS	NS
TE × C <sub>2</sub> H <sub>4</sub> × TR	*	*	*	NS	NS	NS

\*\*\*, \*\*, \*NS Significant at 5%, 1%, and 0.1%, and not significant, respectively.

Received for publication 14 Aug. 1985. Mention of a trademark, warranty, proprietary product, or vendor does not constitute a guarantee by the USDA and does not imply its approval to the exclusion of other products or vendors that may also be suitable. I gratefully acknowledge Roxanne Wiseman and Randall Cubbedge for technical assistance and Victor Chew for conducting the statistical analysis. 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.

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developed.

CI was most prevalent on lemons treated with 10% vegetable oil and those treated with 40% CO<sub>2</sub> after holding for 14 days at 21°C (Table 3). Coating grapefruit with vegetable oil has been reported to reduce CI when the fruit is held for protracted periods at low temperatures (1). Hatton and Cubbedge (7) found that a prestorage treatment of 40% CO<sub>2</sub> for 3 days significantly reduced CI development in grapefruit, but this was not true for lemons. Lemons, like limes, may be injured by CO<sub>2</sub> levels >10% (12).

The lowest incidences of CI were found on film-wrapped fruit and the CO<sub>2</sub> control fruit after holding for 14 days at 21°C. Polyethylene film wraps have been reported to reduce the development of CI (9, 15). Carbon dioxide control lemons were degreened fruit that were merely waxed and held at 21° for 3 days prior to storage. It may be that a temperature of 21° is required to condition lemons against CI during low-temperature storage, although a temperature of 15.5° is optimum for conditioning grapefruit against CI during certain times of the year (7).

There was negligible decay in lemons after 21 days of storage in all treatments (Table 3). Decay increased during the high-temperature holding periods. If one assumes an upper limit of 3% decay for fruit to be still marketable, only the film-wrapped and CO<sub>2</sub> control fruit had acceptable decay levels after 14 days of holding at 21°C. The treatments that showed the lowest incidence of CI also showed the lowest amount of decay. Decay was predominantly green mold, caused by *Penicillium digitatum* Sacc., that enters the fruit through injured tissue (11).

The results of this study indicate film wrapping or holding fruit for 3 days at 21°C after degreening and waxing (CO<sub>2</sub> control) would ameliorate the effects of chilling at 1°. Also, excessively large amounts of CI and decay would be expected when lemons are degreened with 10 µl·liter<sup>-1</sup> ethylene and stored at 1° for 21 days followed by 14 days of holding at 21°.

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Table 2. Effect of ethylene during degreening and storage temperature on chilling injury and decay of lemons averaged over 9 treatments.<sup>z</sup>

Treatment	Chilling injury (%)			Decay (%)		
	After 21 days of storage	After holding at 21°C		After 21 days of storage	After holding at 21°	
		7 days	14 days		7 days	14 days
0 µl·liter <sup>-1</sup> C <sub>2</sub> H <sub>4</sub> , 1 <sup>oy</sup>	0.1	0.2	0.3	0.1	3.2	5.8
0 µl·liter <sup>-1</sup> C <sub>2</sub> H <sub>4</sub> , 10°	0.0	0.0	0.0	0.2	0.7	1.7
10 µl·liter <sup>-1</sup> C <sub>2</sub> H <sub>4</sub> , 1°	7.6	14.7	18.4	0.1	4.2	14.2
10 µl·liter <sup>-1</sup> C <sub>2</sub> H <sub>4</sub> , 10°	0.3	0.6	1.3	0.3	0.7	1.3

<sup>z</sup>Each mean represents 2700 fruit obtained from 3 harvests.

<sup>y</sup>Relative humidity ranged from 80% to 92%.

Table 3. Chilling injury and decay of degreened 'Bearss' lemons averaged over storage temperature and method of degreening.<sup>z</sup>

Treatment	Chilling injury (%)			Decay (%)		
	After 21 days of storage <sup>y</sup>	After holding at 21°C <sup>y</sup>		After 21 days of storage	After holding at 21°	
		7 days	14 days		7 days	14 days
2% oil <sup>x</sup>	2.3	3.4	5.8	0.2	2.2	7.4
10% oil	2.6	5.7	7.5	0.1	1.8	7.3
20% oil	2.3	3.3	4.0	0.0	2.4	9.6
Oil control <sup>w</sup>	2.8	5.3	5.8	0.0	4.2	7.3
H <sub>2</sub> O control <sup>v</sup>	2.4	3.7	4.1	0.0	3.2	6.3
40% CO <sub>2</sub> <sup>u</sup>	1.3	5.6	7.5	0.5	3.1	5.5
CO <sub>2</sub> control <sup>t</sup>	0.6	2.4	2.8	0.3	0.6	1.3
Film wrap <sup>s</sup>	1.6	1.9	3.3	0.3	0.6	0.8
Wrap control <sup>f</sup>	2.2	3.6	4.1	0.2	1.8	6.2

<sup>z</sup>Each mean represents 1200 fruit obtained from 3 harvests.

<sup>y</sup>Relative humidity ranged from 80% to 92%.

<sup>x</sup>30-sec dip in safflower oil in water emulsion plus 0.2% Tween 80.

<sup>w</sup>30-sec dip in 0.2% Tween 80.

<sup>v</sup>30-sec dip in water.

<sup>u</sup>3 days in 40% CO<sub>2</sub> at 21°.

<sup>t</sup>3 days in normal atmosphere at 21°.

<sup>s</sup>Sealed in Cryovac D955 film.

<sup>f</sup>No treatment.

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