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Chilling Injury and Decay of Lemons as Affected by Ethylene, Low Temperature, and Optimal Storage

R.E. McDonald[1], T.T. Hatton[1], and R.H. Cubbedge[2]
U.S. Department of Agriculture, Agricultural Research Service, 2120 Camden Road, Orlando, FL 32803

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Abstract. **'Bearss' lemons (*Citrus limon* Burm f.) stored 21 days at 1°C and held 14 days at 21° sustained 15% chilling injury (CI) compared to 1% after 10° storage and 21° holding period. Decay, predominantly caused by *Penicillium digitatum* Sacc., was negligible during storage at either 1° or 10°, but developed during the holding period at 21°. After storage at 1° or 10° plus 2 weeks at 21°, decay averaged 7.4% and 0.7%, respectively. Fruit size, method of curing, and presence of oleocellosis were not related to CI or decay development.**

Currently, Florida lemons must be fumigated with ethylene dibromide (EDB) to eliminate possible infestations of the Caribbean fruit fly, *Anastrepha suspensa* (Loew), in fruit shipped to other citrus-producing states and Japan. Objections to the use of EDB and possible withdrawal of registration have resulted in 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 (6).

Lemons, like grapefruit, are susceptible to chilling injury (CI) when exposed to temperatures below 10°C for more than 14 to 21 days (1). Hatton and Cubbedge found that grapefruit could be stored at 1° for 21 days without risk of developing CI if the fruit were preconditioned for 7 days at 16° (3). The procedure of holding fruit at 16° without added ethylene is used commercially to degreen lemons in Florida, and the process is sometimes referred to as curing. The use of ethylene at 16° has been found to reduce the time of degreening without appreciably effecting the decay rate (4).

The purpose of this study was to determine the effects of lemons cured with or without ethylene, followed by a low-temperature storage period necessary to qualify as a quarantine treatment against the Caribbean fruit fly.

Fruit were obtained from 2 commercial packinghouses 4 times between 31 Aug. 1983 and 28 Sept. 1983. On each occasion, fruit were harvested into bulk field bins, transported to the packinghouse, and left overnight. The following morning, they were run through a bin drencher containing 600 ppm benomyl. Fruit that were green in color were hand-sized into counts 115, 145 and 165, and transported to the U.S. Horticultural Research Laboratory in Orlando. Initial tests indicated a possible relationship between oleocellosis and CI, so fruit were sorted for the presence of oleocellosis. Lemons were cured without added ethylene at 15.5°C and at 80% to 92% RH. A like sample was degreened with 1 ppm ethylene. When the lemons in individual treatments were sufficiently yellow in color, they were washed, treated with 1000 ppm thiabendazole (TBZ), waxed with Fresh Mark 3202, a water-type wax, randomized into 3 replications of 25 fruit for each of the 3 sizes, and packed in cartons containing one biphenyl pad. Time of degreening averaged 19 days without added ethylene and 14.2 days with 1 ppm ethylene. The fruit then were stored for 21 days at either 1° or 10° under RH conditions of 80% to 92%. Control fruit were not degreened but were held continuously at 1°. These controls were taken from 1° storage after the time required to degreen fruit without ethylene from the same harvest and sorted, similarly treated, packed, and stored at 1°. Commercially treated fruit from the same lots as the test fruit were secured from the packinghouses after packing and stored at 1° or 10°. The commercial fruit were degreened without ethylene.

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

When considering only the effect of storage temperature and excluding the control and commercial pack fruit, CI developed more on lemons stored 21 days at 1°C (average 6.3%) than on those stored at 10° (average 0.1%) (Table 1). This difference was most evident in fruit in the commercial pack, where the difference was statistically significant. In the control fruit that were not cured but kept continuously at 1°, the cumulative percentage value for CI decreased after the initial storage period because of the development of decay on the chilled fruit during holding at 21°. When the values for chilling injury were averaged solely on the basis of storage temperature, excluding the control and commercial pack fruit, CI was minimal (1.0%) in fruit stored at 10° and held 14 days at 21°, whereas it was unacceptably high (15.0%) in fruit stored at 1° and held 14 days at 21°. The method of curing (0 or 1 ppm ethylene) and the presence of oleocellosis had no significant effect on CI development. Hatton and Cubbedge (2) found that grapefruit conditioned for 7 days at 15.5° would not develop CI, but this was not true for lemons even though the lemons were held at 15.5° for a longer period (14.2 to 19 days).

There was negligible decay in lemons after 21 days' storage in all treatments with the exception of the commercial pack that was

Table 1. Chilling injury of cured 'Bearss' lemons stored at 1° or 10°C for 21 days plus 2 weeks at 21°.[z]

Treatment			Chilling injury (%)		
			Immediately after	After holding at 21°C	
C_2H_4 (ppm)	Oleocellosis	Temp. °C[y]	21 days' storage	7 days	14 days
0[x]	–	1	76.8 a[w]	20.9 a	8.1 bc
0[x]	+	1	73.6 a	16.1 a	6.0 c
0	–	1	1.6 c	3.9 b	4.1 c
0	+	1	5.3 c	15.0 a	17.2 ab
0	–	10	0.0 c	0.4 b	0.6 c
0	+	10	0.1 c	2.8 b	2.8 c
1	–	1	8.0 c	18.7 a	18.2 a
1	+	1	10.1 bc	20.6 a	20.6 a
1	–	10	0.1 c	0.3 b	0.4 c
1	+	10	0.1 c	0.2 b	0.2 c
Commercial pack		1	20.0 b	23.1 a	22.4 a
Commercial pack		10	0.2 c	0.0 b	4.0 c

[z]Each treatment represents 900 fruit obtained from 4 harvests of 4 groves.
[y]Relative humidity ranged from 80% to 92%.
[x]Control.
[w]Mean separation in columns by Duncan's multiple range test, 5% level.

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[1]Research Horticulturist.
[2]Biological Laboratory Technician.

Table 2. Decay of 'Bearss' lemons stored at 1° or 10°C for 21 days plus 2 weeks at 21°.[z]

Treatment			Decay (%)		
			Immediately after	After holding at 21°C	
C_2H_4 (ppm)	Oleocellosis	Temp. °C[y]	21 days' storage	7 days	14 days
0[x]	−	1	0.0 b[w]	76.2 a	90.6 a
0[x]	+	1	0.2 b	82.6 a	93.8 a
0	−	1	0.0 b	0.7 c	2.2 e
0	+	1	0.0 b	2.5 c	5.1 de
0	−	10	0.2 b	0.2 c	0.3 e
0	+	10	0.3 b	0.7 c	0.8 e
1	−	1	0.0 b	5.4 c	9.7 de
1	+	1	0.0 b	7.3 c	12.7 d
1	−	10	0.3 b	0.8 c	1.2 e
1	+	10	0.1 b	0.4 c	0.6 e
Commercial pack		1	0.0 b	33.3 b	47.3 b
Commercial pack		10	20.3 a	28.6 b	32.5 c

[z]Each treatment represents 900 fruit obtained from 4 harvests of 4 groves.
[y]Relative humidity ranged from 80% to 92%.
[x]Control.
[w]Mean separation in columns by Duncan's multiple range test, 5% level.

stored at 10°C (Table 2). After 7 days holding at 21°, decay increased in all treatments, particularly the commercial pack stored at 1° and the control fruit that was not cured and kept continuously at 1°. Without considering the method of degreening and the presence of oleocellosis, and excluding the control and commercial pack fruit, the decay average was unacceptably high (7.4%) in fruit stored at 1° and held 14 days at 21°, whereas it was minimal (average 0.7%) in fruit stored at 10° and held 14 days at 21°. Decay was predominantly green mold, caused by *Penicillium digitatum* Sacc., that enters the fruit through injured tissue (5). The treatments which showed the highest amount of decay generally also showed the highest incidence of CI.

As with CI, the method of curing and the presence of oleocellosis had no significant effect on decay development. Size of fruit likewise was not related to CI or decay development.

A low-temperature (1°C) storage period does not appear to be a feasible alternative to EDB as a quarantine treatment against the Caribbean fruit fly, because of resulting poor lemon fruit condition. If ways could be found to ameliorate the CI, however, a low-temperature storage could be used.

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Wholesale and Retail Losses in Grapefruit Marketed in Metropolitan New York

M.J. Ceponis[1] and R.A. Cappellini[2]

Postharvest Research Center, USDA, Cook College, Rutgers University, New Brunswick, NJ 08903

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Abstract. **Losses in white- and red-flesh grapefruit (*Citrus paradisi* Macf.) retailed in metropolitan New York during 1981–83 were 3.6%. There was no difference between the 2 types of fruit. Florida-grown grapefruit had a retail cullage loss of 3.5%. No significant difference in loss occurred between store-prepackaged and loose fruit during retail. Parasitic diseases were responsible for almost half of the culls; rind breakdown and mechanical damage accounted for most of the remainder. Sampling at the wholesale level revealed a potential cullage of 1.4%.**

The consumption of fresh grapefruit in metropolitan New York is exceeded only by potatoes, lettuce, oranges, and apples (9). The volume of this major citrus crop delivered to the New York market in 1982 was almost 71,000 MT, a 30% increase from 1977 (9). Florida supplies the New York market with more than 90% of its grapefruit, and California supplies most of the remainder.

As a continuance of a USDA study of market losses of major fresh fruit and vegetable crops (1, 2, 3, 4, 5, 6, 7, 10), this report deals with the condition of grapefruit at wholesale and the subsequent extent of loss in retailing the crop in metropolitan New York. The information could provide valuable guidelines for reducing losses and preserving product quality.

Information on the wholesale condition of grapefruit was obtained by visiting the New York City Terminal Market at Hunts Point and warehouses of leading food chain organizations in metropolitan New York periodically from 1981 to 1983. The receivers permitted us to examine grapefruit on their premises shortly after delivery. When the cause of waste could not be determined immediately the culls were brought to our laboratory, and the cause(s) identified through macroscopic and microscopic examination and culturing of microbial pathogens.

Retail losses were obtained through cooperation of 9 supermarkets, a minimum of 2 each from low, middle, and high income locations in metropolitan New York. Stores were visited once or twice weekly throughout most of the year. Fruit displayed in some stores often were from the same lot(s) sampled previously at wholesale.

Data were obtained from store personnel or from our examination of the fruit. Loss data were based on a 1–3 day test period each week. When necessary, the cull specimens were brought to the laboratory for a definitive diagnosis.

More than 59,000 white- and red-flesh grapefruit were examined at terminal market wholesale outlets and food-chain distribution warehouses during the 3-year study (Table 1). Florida and California fruit made up 85.7% and 12.8% of the total, respectively, with the remainder from Texas and Arizona. Of the 815 culls (1.4%), parasitic activity ac-

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[1]Research Plant Pathologist.
[2]Professor, Dept. of Plant Pathology.