Commercial Use of Long-term Storage of Lemon with Intermittent Warming

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Long-term storage of lemon [*Citrus limon* (L.) Burm] at 13°C for 3 months and longer resulted in a high incidence of rot. The remaining sound fruit became dry, overripe in color, and therefore unmarketable. Storage at <10°C caused chilling injury, including internal membranosis, peel pitting, and changes in juice composition (4). Intermittent warming for 7 days at 13° following 21 days at 2° eliminated chilling injury development in 'Eureka' and 'Villa franca' lemon. Lemons could be kept in storage for 6 months or longer and retain their marketing quality without chilling injury (5). Herein are presented the results of 2 years of commercial use of long-term storage of lemons at suboptimal temperature with intermittent warming.

Lemons were harvested, handled, and treated at the packinghouse and stored in a large room. Technical facilities were available for cooling to 2°C and heating to 13°. Relative humidity was kept at a constant 95%, and there was one-half an air change per hour during the 21 days at cold storage and two air changes per hour during the 7 days of intermittent warming.

During the period 8–24 Jan. 1984, mature, light green, and silver lemons were washed with tap water, immersed for 3 min in 0.5% sodium orthophenyl-phenate solution (pH 11.8, 36°C), rinsed with tap water, dried, and coated with storage wax containing 2.0 g·liter^{-1} 2–(thiazol-4yl)-benzimidazole (thiabendazole) plus 2.0 g·liter^{-1} (allyl-1(dichlorophenyl)-2-imidazole-1-ylethyl ether (imazalil) and 0.1·g liter^{-1} 2,4-D isopropyl ester. The lemons were stored in plastic bins (200 kg capacity). After 5 months at 2° with intermittent warming at 13°, the lemons again were disinfected with 2.0% sodium orthophenyl-phenate foam, rinsed, and coated with a common polyethylene water-emulsion wax, wrapped with plain paper, and packed in cartons or in wooden crates. Fruit were taken to the harbor in open trucks, followed by 10 days in a refrigerated ship (10°) to Europe. Once a month during storage, juice chemical composition and rate of respiration were examined on lemons from 12 random bins distributed throughout the storage room. During 5 months storage, the juice content increased from 31.5% ± 0.7% at harvest to 36.1% ± 0.6%. Acid content ranged from 6.9% ± 0.1% to 6.1% ± 0.2%, and total soluble solids from 8.8% ± 0.1% to 8.1% ± 0.2%. Ethanol increased from 227.1 ± 50.1 to 441.5 ± 28.7 ppm and respiration rate ranged from 12.4 ± 2.2 to 16.6 ± 2.1 mg CO_2/kg per hr. Samples (14 kg each) from 34 cartons, collected over 3 days of packing, were held for 4 weeks at 20°. Fruit rot, caused mainly by *Geotrichum candidum* (Lk. ex Pers.) and *Alternaria citri* (Ell. & Pierce), ranged between 0% and 0.6% per carton, whereas the total average rot did not exceed 0.35% ± 0.21% (n = 4000 fruit).

During 1984–85, storage began in late December, when most lemons had matured and reached the desired light-green and silver color. Packinghouse treatments and storage practices were similar to those of the previous year. After 7 months of storage, the lemons were packed and transported to Europe by refrigerated ships (10°C) on two dates, 10 and 28 July 1985. Upon their arrival at the port, the lemons were transported by refrigerated truck (10°) to the market. Juice composition and flesh taste after 7 months storage, plus 2 weeks at 17° from lemons from the first packing date, are shown in Table 1. Similar results were obtained in lemons from the second packing date. The lemons arrived in Europe with good external appearance, fair firmness, and with a negligible amount of fruit with advanced color and decay. The juice content of samples from 10 packed cartons was between 44.0% and 46.3%, total soluble solids 7.8% to 9.4%, acid 5.1% to 5.7%, and sugar : acid ratio 1.4:1 to 1.5:1. Slight membranosis, 10% to 17%, was found in the fruit. No major external or internal quality changes were observed in these lemons during a further month of holding at an ambient room temperature of 17° to 18° C.

Increases in storage life and resistance to chilling related with intermittent warming periods during cold storage has been reported in grapefruit (3, 6), peaches (1, 2), cucumbers and sweet peppers (9), potatoes (7), and tomatoes (8), but to the best of my knowledge, the intermittent warming has not been used for storage of chilling sensitive commodities as done here for lemons.

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Table 1. Juice chemical composition[z] and taste[y] of lemons after 7 months of storage plus 2 weeks at 17° C.[x]

Fruit size (mm)	No. lemons per carton	Juice (%)	Acid (%)	TSS (%)	TSS : acid ratio	Ethanol (ppm)	Taste	Off flavor[v]
70–75	90	37.3 ± 1.4	5.9 ± 0.1	8.6 ± 0.3	1.45 ± 0.06	816.9 ± 30.8	2.7 ± 0.1	0.25 ± 0.09
60–65	125	39.8 ± 0.5	5.8 ± 1.0	8.6 ± 0.5	1.47 ± 0.02	800.5 ± 76.3	2.4 ± 0.1	0.79 ± 0.19
55–60	160	36.7 ± 0.4	6.6 ± 0.3	8.4 ± 0.0	1.50 ± 0.80	747.6 ± 20.3	2.4 ± 0.1	0.73 ± 0.18

[z]Means from three replicates each of five fruits, ±SD.
[y]From lemon flesh, means of results from 24 tasters.
[x]First packing at 10 July 1985. Weight loss (water and decay) was 9.6%. Lemon packaging displayed to 49% for export, 24% for local market, and 27% for processing.
[w]Graded as: tasty, 3; edible, 2; nonedible, 1.
[v]Graded as: none = 0, little = 1.