

The Effect of Sub-freezing Temperatures on Fruit Quality and Seed Viability of 'Lula' Avocado¹

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Abstract. Mature 'Lula' avocado fruits (*Persea americana* Miller) were exposed to temp ranging from -2.2 to -8.9°C for 4 hr in a freeze chamber. No off-flavors or discoloration developed during a 7-day ripening period (25°C) after temp of -5.6° and above. Temp of -6.7° and -7.8° caused discoloration and decay of the outer part of the mesocarp; the inner region remained hard, green, and unpalatable. Following the -8.9° treatment, the entire mesocarp decayed. Insertion of thermocouples into the fruits decreased cold tolerance 1°. Seed germination was reduced to less than 50% of normal in the -4.4° to -6.7° range, then decreased to 0 at -8.9°. Tissue temp curves showed heat release coincident with tissue damage, indicating internal ice formation.

Avocados, like other subtropical fruits, are often grown in areas subject to damaging freezes. There are cultivar differences in cold hardiness and 'Lula' is one of the most cold tolerant Guatemalan-West Indian hybrids (8, 9) able to withstand -2.8°C without leaf or wood damage (3). Observations after freezes in Florida are somewhat contradictory, with a report of little fruit injury after temp as low as -4.4°C (7) and 100% injury after 5 hr below -3.3°C with a -4.4°C min (5). The purpose of the present study was to determine, under controlled conditions, the temp at which mature 'Lula' avocado fruits become unpalatable and the seeds lose their viability.

Fifteen fruits were harvested daily from a 7-year-old 'Lula' tree over the period Dec. 9 to Dec. 16, 1970. The fruits had reached maturity, were of uniform size, and were subjected to sub-zero temp in a walk-in freeze chamber programmed to lower the temp from 1.7°C to min of -2.2, -3.3, -4.4, -5.6, -6.7, -7.8, and -8.9 at the rate of 1.1 °C per hr, maintain the min for 4 hr ($\pm 1^\circ$) and then raise the temp to 1.7°C at the same rate (Table 1). The tests were made in daily sequence.

Copper-constantan thermocouples (24 gauge) were fastened to the skins of 10 fruits with masking tape. We placed the fruits on a wooden support so that they rested on the point of attachment of the thermocouples. Five additional fruits had thermocouples attached to them the same way, but a second thermocouple was also inserted into the mesocarp deep enough to be in contact with the seeds. Tissue temp were printed every

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4 min by a multipoint recorder.

Table 1. Fruit size, % decay, % seed germination, appearance and flavor of 'Lula' avocado fruit exposed to temp in the -2.2^o to -8.9^oC range for 4 hr.

Min temp (°C)	Circumference (cm)	Wt (g)	Decay (%)	Seed ^y germ. (%)	Appearance	Flavor
<i>Means of 10 fruits with 1 thermocouple fastened externally</i>						
-2.2	25.7	323	0 c ^z	87	Bright green	Good
-3.3	25.9	325	0 c	87	Bright green	Good
-4.4	26.3	348	0 c	47	Bright green	Good
-5.6	27.3	375	0 c	31	Bright green	Good
-6.7	26.7	362	72 b	46	External decay; hard green undecayed core	Inedible
-7.8	26.4	354	100 a	7	External decay; some green tissue	Inedible
-8.9	25.8	327	100 a	0	Decayed	Inedible
<i>Means of 5 fruits with 1 thermocouple fastened externally, 1 internally</i>						
-2.2	25.3	301	0 c		Bright green	Good
-3.3	25.5	317	0 c		Bright green	Good
-4.4	27.3	285	0 c		Bright green	Good
-5.6	26.9	357	32 b		Decay around thermocouple puncture	Undecayed parts good
-6.7	25.5	348	98 a		Decayed; hard green undecayed core	Inedible
-7.8	27.1	382	100 a		External decay, some green undecayed tissue	Inedible
-8.9	26.3	356	100 a		Decayed	Inedible

^yBased on all 15 seeds collected at each freeze test.

^zMeans in columns followed by different letter are different at the 1% level.

After each freeze test we weighed the fruits, measured their circumference, and stored them for 7 days in a 25°C room for ripening. We then checked their appearance and tasted each fruit. The seeds were removed and planted in a raised bed filled with a perlite-peat-moss mixture in a greenhouse (temp range 15 to 37°). We recorded the no. of seeds germinating over a 5-months period.

Six other fruits picked in the middle of the mid-December test period were peeled and cut into small pieces for freeze-drying in a vacuum chamber. Fresh and dry wt of 3 composite samples, each made up of material from 2 fruits, were recorded. After grinding to 20-mesh size, a 200-mg aliquot (dry wt) from each composite sample was analyzed for total and reducing sugars, using the extraction method of the A.O.A.C. (1) and the analysis method of Chan and Cain (2). Total fats were determined gravimetrically by the A.O.A.C. method (1) using 2 g of freeze-dried material.

Table 1 shows that 'Lula' avocado fruit tolerated -5.6°C for 4 hr without any effect on appearance and taste. Exposure to -6.7° and below, however, resulted in widespread decay of the outer layers. The inner part of the mesocarp was not invaded by rot organisms, but remained hard and green. The amount of green, hard pulp decreased with temp, and after 4 hr of -8.9° the entire mesocarp decayed during the 7-day ripening period.

The tissue temp curves in Fig. 1 show that the surface temp of the fruits paralleled the air temp from -2.2 to -4.4°C. At temp lower than -4.4° the formation of ice released latent heat. This heat-release had the greatest effect in raising min tissue temp during exposure to -7.8°. Insertion of a thermocouple caused ice crystal formation and freeze

damage at -5.6° , 1° higher than in intact fruits. The point of max temp rise was shifted from -7.8° to -6.7° . Some ice seems to have formed in unpunctured fruits during exposure to -5.6° , but apparently not enough to cause discoloration, off-flavors, or to prevent ripening.

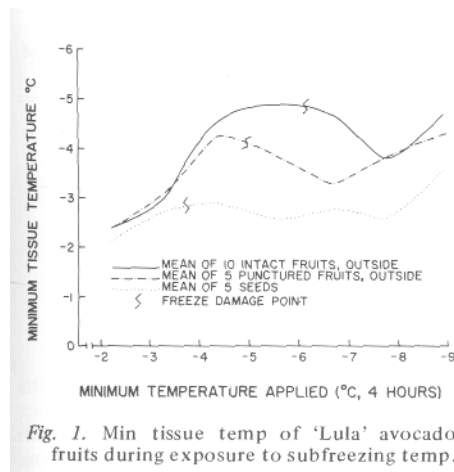


Fig. 1. Min tissue temp of 'Lula' avocado fruits during exposure to subfreezing temp.

Seed germination was first reduced to below normal after -4.4°C , but then decreased further only after -7.8° treatment reflecting the rather small differences in seed temp in that range. No seeds survived the -8.9° treatment (Table 1).

The sugar, oil, and water content of the 6 fruits analyzed was uniform (% of fresh wt: 1.85 ± 0.04 reducing sugars, 1.93 ± 0.01 total sugars, 9.96 ± 0.05 oil, $78.4 + 0.8$ water) and their oil level in the same range as in 'Lula' avocados in Florida at the same time of the year (4, 6).

Among subtropical fruits avocado is unusual in bearing fruit more cold hardy than the tree. If harvested quickly after a freeze and stored at 10°C , there is little effect on quality, and the fruit can be sold after representative samples are softened at 20° and 25° in order to evaluate the extent of freezing damage (5, 7). The results of the present experiment show that the min temp after which this can be done with 'Lula' avocados is approximately -6° . Other cultivars react differently (5, 7) and separate min temp have to be established for them.

Because the demand for replacement trees is particularly heavy after freezes, the viability of seed from cold-damaged fruits is of interest. 'Lula' has been successfully used as a rootstock in Texas, and taking into account an approx germination rate of 50%, seed from fruit exposed to -7°C could be used.

Noteworthy is the decreased cold hardiness of fruits punctured with thermocouples. Although fine, 24-gauge wire was used, enough heat appears to have been conducted out of the fruit tissues to raise the damage point by 1°C because of earlier ice formation.

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