The Effect of Sub-freezing Temperatures on Fruit Quality and Seed Viability of 'Lula' Avocado[1]

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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 (± 1°) 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 4 min by a multipoint recorder.

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.

Seed germination was first reduced to below normal after -4.4°C, but then decreased further only after -7.8°

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

Min temp (°C)	Circum-ference (cm)	Wt (g)	Decay (%)	Seed[y] germ. (%)	Appearance	Flavor
Means of 10 fruits with 1 thermocouple fastened externally						
-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
Means of 5 fruits with 1 thermocouple fastened externally, 1 internally						
-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

[y]Based on all 15 seeds collected at each freeze test.
[z]Means in columns followed by different letter are different at the 1% level.

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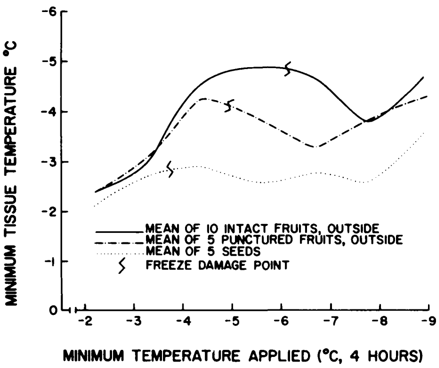

Fig. 1. Min tissue temp of 'Lula' avocado fruits during exposure to subfreezing temp.

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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The Freezing Point of Detached Leaves as a Measure of Cold Hardiness of Young Budded Citrus Plants[1]

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Abstract. **The freezing point of detached leaves of young, budded, container-grown 'Hamlin' orange plants was an acceptable measure of cold hardiness. Controlled freezing established that the mean leaf freezing point (MLFP) of detached leaves estimated cold hardiness within 0.86°C and was useful to predict the degree of damage to plants exposed to subfreezing temperatures.**

Field observations of grove trees are used to evaluate cold hardiness of citrus (2, 3, 5). Since natural freeze periods vary in frequency and intensity, conditions before, during, and after, are never the same. Thus, objective comparisons of observational data from the field have been difficult. Attempts have been made to subject entire plants in the grove to controlled freezing conditions and measure the degree of damage (1, 6). This method requires expensive, portable freezing equipment.

Others (8, 9) have subjected young citrus plants to damaging temp in freeze chambers usually with small plants to accommodate the units. Freeze damage to small, container-grown plants may not necessarily be the same as damage to large plants exposed to similar conditions. Further, this method is not satisfactory for field surveying of hardiness nor for evaluating hardiness in a single plant since the plant must be sacrificed to make the hardiness determination. These limitations have stimulated interest in hardiness testing using explants.

The freezing point of detached leaves has been used to evaluate the cold hardiness of citrus plants (4, 7, 8, 9). Gerber and co-workers (4, 7) demonstrated that the leaf freezing point is a valid indicator of the cold tolerance of young, container-grown citrus plants; however, Young and Peynado (8, 9) questioned the reliability of leaf freezing point as a measure of cold hardiness of citrus leaves. The research reported here evaluates leaf freezing points as estimates of cold hardiness of budded citrus plants which are older and larger than those used by Gerber or Young (4, 7, 8, 9).

The method of Gerber and co-workers (4, 7) was modified to determine leaf freezing points. An Admiral Model CF 1556 chest-type freezer was used in place of an alcohol-ice bath for freezing detached leaves. The freezer was fitted with an insulated lid with a 7.5 x 7.5 cm entry port. Leaf samples were attached to a thermistor on the end of a 50-cm-long wooden rod and lowered through the entry port to 5 cm above the floor of the freezer. Freezer temperature at this point was -16.6°C ± 1.1°.

'Hamlin' orange trees budded on rough lemon rootstock in May, 1968 were planted in May, 1969 in 15-cm pots and grown under natural outdoor environmental conditions until used in December, 1969. Fully expanded, mature leaves from the first 6 leaves on a twig were used as samples for freezing. The freezing points of 3 leaves were averaged to obtain the MLFP of the plant. Lethal temp of intact plants were determined in a walk-in freeze chamber equipped with forced air circulation. The desired temp was preset, plants under test were placed in the chamber, the pot and base of the stem protected from freezing by a layer of vermiculite and thermocouples were attached to leaves of the plants. The temp exposure in the freeze chamber was measured and recorded with 22-gauge copper-constantan thermocouples and a 20-point Honeywell recorder. Chamber and plants were maintained at the desired temp for 1 hr; plants were then removed to a warm greenhouse for 2 weeks and damage evaluated.

Sensitivity test. A preliminary test was made to determine the sensitivity of the leaf freezing point method. Twenty uniform plants of 'Hamlin' orange on rough lemon rootstock growing under natural outdoor environmental

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