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QUALITY OF 'BOOTH 8' AND 'LULA' AVOCADOS STORED IN A CONTROLLED ATMOSPHERE

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Abstract. Storage of 'Booth 8' and 'Lula' avocados in a controlled atmosphere (CA) of 2% O_2 and 10% CO_2 at 40°, 45°, and 50° F. for 20, 40, and 60 days resulted in more acceptable fruit than comparable storage in air. All 'Lula' and 63% of 'Booth 8' avocados were acceptable after 60 days in CA at 45°. No significant differences in quality were detected between 'Lula' or 'Booth 8' avocados stored in CA at 40° and those at 45°. 'Booth 8' fruit had less anthracnose decay at 40° but more internal chilling injury than at 45°. The development of anthracnose and chilling injury was severe in avocados stored in air and none were acceptable after 40 days. Slight internal chilling injury developed in 'Booth 8' avocados, but none in 'Lula,' stored in CA for 60 days at 40°. External chilling injury of avocados was slight after 60 days in CA.

A controlled atmosphere (CA) of 1 to 2% O_2 and 10% CO_2 is superior to air for prolonged storage of 'Lula' avocados (3, 4, 5, 8). Storage life is increased by removal of ethylene from the storage chamber (5). Concentrations of O_2 greater than 2% are increasingly less beneficial for CA storage of avocados (3, 4). Experience in CA work at the U. S. Department of Agriculture laboratory in Miami, Florida, has shown that avocados are damaged when the O_2 concentration is less than 1% for several days. The use of 2% O_2 provides a margin of safety against low-O_2 injury and is more feasible commercially to maintain than a lower concentration. The use of 7% (3) and 9% (4), but not 5%, CO_2 in conjunction with 1% O_2 was beneficial to the avocados. In recent studies a CA of 2% O_2 and 10% $C0_2$ has been used (5, 8).

Table 1. Characteristics of 'Booth 8' avocados after storage for 20, 40, and 60 days in a controlled atmosphere (CA) of 2% O_2 and 10% CO_2 or in air at 40°, 45°, or 50° F. followed by softening at 70°.[z]

Storage time and temperature (°F)	Acceptable fruit[y] (%)		Softening time[x] (days)		External chilling injury[w] (rating)		Decay[w] (rating)	
	Air	CA	Air	CA	Air	CA	Air	CA
20 Days								
40	80abc	93ab	4.8	5.8	1.2	0.8	1.2fg	0.6g
45	57de	100a	3.8	5.9	1.1	0.7	2.3de	0.6g
50	33fg	60cde	1.6	5.2	1.3	0.6	3.6abc	1.0g
40 Days								
40	17gh	73bcd	--[v]	6.4	1.1	0.4	3.2bc	2.2de
45	0 h	67cd	--	5.5	--	0.1	4.0a	2.4de
50	0 h	43ef	--	3.8	--	0.4	4.0a	2.9bcd
60 Days								
40	0 h	53def	--	7.4	--	0.2	4.0a	1.8ef
45	0 h	63cde	--	5.2	--	0.2	4.0a	2.6cd
50	0 h	17gh	--	--	--	--	4.0a	3.2bc

[z]Each figure is an average of data from two seasons using 10 and 20 fruits per treatment in 1970 and 1971, respectively. Means in comparable columns not followed by a letter in common are significantly different at the 5% level (Duncan's Multiple Range Test).

[y]Acceptability based on appearance, relative freedom from moderate or severe decay, discoloration, and palatability.

[x]Prestorage softening time 6.5 days.

[w]Ratings based on percentage of total surface area affected: (0) None; (1) 1-2%, Trace; (2) 3-10%, Slight; (3) 11-20%, Moderate; (4) 21-100%, Severe.

[v](--) Readings not made because of severe decay.

MATERIALS AND METHODS

Mature 'Booth 8' avocados were obtained on day of harvest from packinghouses in the Homestead, Florida area on October 28, 1970 and October 18, 1971. Mature 'Lula' avocados were harvested on January 25, 1972. Fruits for each test were randomized and divided into samples of 10 fruits each in 1970 and 20 fruits each in 1971 and 1972. One sample was placed at 70° F. in air to determine softening time, to the nearest day, and quality before storage. Fruits were considered ripe when they attained uniform edibility and softness as indicated by slight finger pressure (6). The other samples were placed in 30-gal. Chambers and stored in air or CA at 40°, 45°, or 50° F. Three samples were placed in each chamber. A tray of water was placed in each chamber to maintain

a relative humidity of 95 to 100% as measured with an electronic hydrometer. A shallow tray (10-in. x 6-in. x 2-in.) containing 1/2 lb. of "Purafil,"[2] activated alumina pellets impregnated with potassium permanganate, was placed in each chamber to absorb ethylene (5). A paper bag containing 1 lb. of hydrated lime was placed in the air chamber to absorb CO_2. The CA tests were conducted with a closed system in which the atmospheres were re-circulated using small diaphragm pumps. The CA atmosphere was measured daily and maintained at 2.0 ± 0.5% O_2 and 10.0 ± 1.0% CO_2. The O_2 concentration was measured with a Beckman 777 oxygen electrode and the CO_2 concentration with an Orsat gas analyzer. Carbon dioxide concentrations were maintained by removing excess CO_2 by varying the time of pumping the atmosphere through a scrubber of hydrated lime, or by adding C O_2 as needed (3). Oxygen concentrations were adjusted by either removing 0, by flushing the chamber with N, or by adding O_2. Samples of avocados from air and CA chambers were withdrawn after 20, 40, and 60 days. The fruits were examined externally on removal and both externally and internally after softening at 70° as described previously (6, 8).

Table 2. Internal chilling injury of 'Booth 8' avocados stored in a controlled atmosphere (CA) of 2% O_2 and 10% CO_2 or in air at 40°, 45°, 50° F. followed by softening at 70°.[z]

Temp	Internal chilling injury (rating)[y]					
	20 Days		40 Days		60 Days	
°F.	Air	CA	Air	CA	Air	CA
40	0.2	0.1	1.0	0.4	3.9	1.1
45	0.6	0.0	--[x]	0.7	--	0.5
50	--	0.0	--	0.0	--	0.0

[z]Each figure is an average of data from 20 fruits per treatment (1971 test).

[y]Ratings based on severity and extent of flesh discoloration : (0) None; (1) Trace; (2) Slight; (3) Moderate; and (4) Severe.

[x](--) Observation masked by decay.

Decay and external chilling injury ratings were based on total surface area affected: (0) none; (1) 1-2%, Trace; (2) 3-10%, Slight; (3) 11-20%, Moderate; and (4) 21-100%, Severe. The minimum standard for acceptability of avocados after storage and softening was a good appearance depending mainly on relative freedom from moderate or severe decay and external chilling injury, absence of moderate or severe internal chilling injury, uniform ripeness, and acceptable palatability (no off-flavors) . Sound avocados from each sample of fruit were rated by 3 staff members for palatability using a numerical index (4-excellent, 3good, 2-fair, and 1-poor).

Data were analyzed by mean separation of the functional analyses of variance and multiple comparisons (2).

RESULTS

Acceptability of avocados depends on general appearance, softening time, and palatability. Appearance is affected adversely by decay and chilling injury. Softening time is an index of post-storage life at room temperature (70° F.)

'Booth 8' *Avocados.* After softening in air at 70° F., 'Booth 8' avocados stored at 40° in CA for 40 days were 73% acceptable, while comparable fruits in air for 20 days were 80% acceptable (Table 1). Acceptability of fruits in air for 40 days was 17% at 40° and 0% at 45° and 50°. Avocados stored at 40° in CA did not have significantly better quality after 40 or 60 days than comparable fruits stored at 45°. Avocados at 45° in CA for 60 days were 63% acceptable, while comparable fruits in air for 20 days were 57% acceptable. Acceptability of avocados stored at 50° in CA for 40 days was only 43%.

At 40° F., softening time of avocados increased 14%, from 6.5 to 7.4 days, after 60 days in CA compared to a decrease of 26% to 4.8 days after 20 days in air. At 45°, softening time decreased 20% to 5.2 days after 60 days in CA, while that for comparable fruits decreased 42% to 3.8 days after 20 days in air. At 50°, softening time decreased 42% to 3.8 days after 40 days in CA, while that for comparable fruits decreased 75% to 1.6 days after 20 days in air.

External chilling injury ratings of 'Booth 8' avocados after 60 days in CA averaged trace; ratings for comparable fruits after 20 days in air averaged slight (Table 1). Internal chilling injury ratings, though greatest after 60 days at 40°F., averaged slight in CA but severe in air (Table 2).

'Lula' Avocados. After softening in air at 70° F., 'Lula' avocados stored in CA at 40° or 45° for 60 days were 100% acceptable; those at 50° were 87% acceptable (Table 3). Comparable fruits in air for 40 days were not acceptable. More avocados stored in CA for 60 days were acceptable than in air for 20 days. Average softening time decreased 22%, from 6.4 to a low of 5.0 days, after 60 days in CA compared to a decrease of 52%, from 6.4 to a low of 3.1 days, after 20 days in air. External chilling injury ratings after 60 days in CA averaged trace at 50° and slight at 40° and 45°. External chilling injury ratings after 20 days in air averaged moderate at 50° and after 40 days averaged severe at 40° and 45°. No internal chilling injury developed in avocados stored in CA. Anthracnose decay in avocados in CA for 60 days followed by softening averaged trace amounts at 40°, 45°, or 50°. Anthracnose in comparable avocados in air for 40 days averaged: severe at 50°; slight at 45°; and trace at 40°.

Table 3. Characteristics of 'Lula' avocados after storage for 20, 40, and 60 days in a controlled atmosphere (CA) of 2% O_2 and 10% CO_2 or in air at 40°, 45°, or 50° F. followed by softening at 70°.[z]

Storage time and temperature (°F.)	Acceptable fruit[y] (%)		Softening time[x] (days)		External chilling injury[w] (rating)		Decay[w] (rating)	
	Air	CA	Air	CA	Air	CA	Air	CA
20 Days								
40	80ab	100a	3.3	6.0	1.5	0.8	0.1	0.1
45	73b	100a	3.4	5.6	1.3	0.4	0.0	0.0
50	47c	100a	3.1	6.0	2.1	0.3	0.3	0.5
40 Days								
40	0d	100a	--[v]	5.1	4.0	0.9	0.8	0.2
45	0d	93ab	--	5.5	3.7	1.1	1.5	0.3
50	0d	100a	--	5.4	--	0.9	4.0	0.3
60 Days								
40	0d	100a	--	5.0	4.0	1.1	--	0.1
45	0d	100a	--	5.3	--	1.7	--	0.1
50	0d	87ab	--	5.0	--	0.7	--	0.7

[z]Each figure represents the average of data using 20 fruits per treatment.

[y]See Table 1. Means for acceptable fruits not followed by a letter in common are significantly different at the 5% level (Duncan's Multiple Range Test).

[x]Prestorage softening time--6.4 days.

[w] and [v]See Table 1.

DISCUSSION

Anthracnose is the major storage disease of avocados. Infection occurs in the field but the fungus remains dormant until the avocado begins to soften (1). The hyphae then invade the peel and pulp and dark spots begin to appear. Low O_2 storage reduces the respiration of avocado and thereby prolongs the time that the fruit remains in a firm green condition resistant to fungal invasion.

In the present study the 'Booth 8' avocados developed more internal chilling injury and anthracnose decay than 'Lula' avocados. Results of previous storage tests (6) suggest that 'Lula' are more resistant to chilling injury than 'Booth 8' avocados when stored in air below 55°. The increased chilling injury of 'Booth 8' avocados may possibly have weakened the tissue and increased susceptibility to fungal invasion as reported for other plant tissues (7).

Less chilling injury developed in avocados stored in CA than in air. The CO_2 component of the CA atmosphere may be concerned primarily with reduction in chilling injury (9) but

additional tests are needed to verify this point.

CA storage tests with Florida avocados suggest that in a CA room at 45 °F. with 2% O_2 and 10% CO_2 and absorption of evolved ethylene 'Booth 8' avocados could be expected to remain in marketable condition for 20 days. This represents about onethird more fruits than usually could be kept in air under the same conditions. In the present study about two-thirds of the 'Booth 8' avocados were still acceptable after 60 days in CA at 45°. Most 'Lula' avocados, on the basis of this and other (2, 4, 6) CA tests, could be in marketable condition for 40 days. In the present study, however, all were acceptable after 60 days in CA at 45°. At 50°, decay is a major problem and losses in CA after 60 days have varied from 13% (present study) to 52% (4). Since results indicate that development of chilling injury is retarded in CA, decay losses can be reduced by storage at 45°. The success of CA storage for avocados will depend to a considerable degree on proper maintenance of the recommended atmosphere and the use of mature green fruits free of wounds and decay.

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[2]Manufactured by Marbon Division, Borg-Warner Corp., Washington, W. Va. Use of trade name and manufacturer's name is for identification purposes only and is not intended as a recommendation by the USDA of the article mentioned over similar articles by other manufacturers.

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