HortScience 11(5):491–492. 1976.

Low Pressure (Hypobaric) Storage of Avocados[1]

Donald H. Spalding and William F. Reeder
Agricultural Research Service, U.S. Department of Agriculture, Subtropical Horticulture Research Station, Miami, FL 33158

Additional index words. postharvest preservation, *Persea americana*, subtropical fruits

Abstract. **'Waldin', 'Booth 8', and 'Lula' avocados (*Persea americana* Miller) were not acceptable when softened at 21.1°C in air under normal pressure, if they had been stored for 4–6 weeks at 7.2–10.0°, 98–100% relative humidity, and an atmospheric pressure of 76, 152, or 760 mm Hg. 'Waldin' avocados were acceptable when softened after 25 days at 7.2°C and 91 mm Hg provided that storage was in 2% O_2 and 10% CO_2. The results suggest that atmospheres both low in O_2 and high in CO_2 are necessary for the successful storage of avocados under low pressure. Under these conditions the low pressure system is comparable to the standard controlled atmosphere system in which avocados are stored in 2% O_2 and 10% CO_2 at normal atmospheric pressure.**

Hypobaric or low atmospheric pressure (LP) storage is a patented method (1, 3) claimed by Burg (2) to extend "the useful life of fresh fruits, vegetables, cut flowers, cuttings, potted plants, meat, poultry, fish, shrimp, and other metabolically active matter." He reported, for example, that 'Lula' avocados remained firm for 3½ months under hypobaric conditions and then ripened normally upon removal. This length of storage under LP is almost twice that reported (4, 5) for 'Lula' avocados held in a controlled atmosphere (CA) under normal atmospheric pressure (NP). We report the effect of LP storage on decay, chilling injury (CI), and overall quality of 3 Florida avocado cultivars.

Freshly harvested 'Waldin', 'Booth 8', and 'Lula' avocados were selected free of decay and blemishes from bulk bins at local packinghouses. Avocados were sorted by weight into comparable samples of 20–25 fruit for each treatment. Decay and CI of avocados after storage and softening were rated on the basis of percentage of surface area of rind affected: 1=trace (up to 3%–barely noticeable), 2=slight (up to 10%–noticeable, but not objectionable), 3=moderate (10 to 20%–uacceptable), and 4=severe (more than 20%–unacceptable).

CA and LP storage tests were run as described previously (5, 7). Storage atmospheres were air, 2% O_2, 4% O_2 and 2% O_2 with 10% CO_2. To obtain the last mentioned atmosphere under LP, pure CO_2 and O_2 from gas cylinders were metered into a 150-ml glass mixing chamber and their flow rates regulated to supply a mixture of 16.7% O_2 and 83.3% CO_2 (amounts corresponding to 2% O_2 and 10% CO_2 at LP). Flow into the chamber was controlled at 110 ml/min (1 air change/hr). Oxygen concn were maintained at ± 0.5% and CO_2 concn was kept at ± 1%. No CO_2 was added to the air check, since previous studies (6) showed that 10% CO_2 was not beneficial unless mixed with 2% O_2. Chamber pressures were 76, 91, 152 and 760 mm Hg and were maintained at ± 2 mm Hg. The relative humidity in each LP and NP chamber was maintained at 98–100% as determined by a humidity sensing element (Hygrodynamics, Inc., Silver Spring, MD). Temperatures reported are accurate to ± 0.5°C.

'Lula' avocados stored at 10°C for 6 weeks under all conditions of atmospheres and pressures except one (Table 1) developed severe anthracnose decay and moderate to severe external CI. Internal CI was either absent or slight. Most of the avocados stored under LP or in air (21% O_2 with 0% CO_2) under NP were not acceptable after softening at 21.1°; 70% of the avocados stored in the standard CA conditions (2% O_2 with 10% CO_2) under NP were acceptable after softening. This atmosphere inhibited the development of decay and CI as previously shown (4, 5, 6). These avocados were hard on removal from storage and softened in 4.5 days at 21.1°. Results were similar to these under comparable conditions for 'Waldin' and 'Booth 8' stored 4 and 5 weeks, respectively. Storage of all 3 cultivars for 4–6 weeks at lower temp (4.4 and 7.2°) and at 76 mm Hg, but without CO_2 enrichment, also resulted in unacceptable fruit.

The absence of CO_2, a gas essential to the successful storage of avocados in CA, was considered to be a possible reason for the failure of avocados to store well under LP. We, therefore, tested the effect of CO_2 enrichment on the ability of the LP system to maintain the quality of avocados (Table 2). Regardless of atmospheric pressure, fruit stored in 2% O_2 with 10% CO_2 developed little decay and CI, and were mostly acceptable; whereas all fruit stored in 2% O_2 without CO_2 developed severe decay and CI, and were unaccep-

Table 1. Quality of 'Lula' avocados stored at 10°C and 98–100% relative humidity for 6 weeks in various atmospheres under normal (NP) or low atmospheric pressure (LP) and then softened at 21.1° in air under NP.[z]

Storage conditions						
Type	(mm Hg)	O_2 (%)	CO_2 (%)	Decay index[y]	External CI index[y]	Acceptable fruit[x] (%)
NP	760	21	0	4.0	4.0	0
NP	760	2	10	1.8	0.1	70
LP	76	2	0	4.0	2.7	0
LP	152	4	0	4.0	4.0	0

[z]Each figure is the mean for 40 avocados (2 replications of 20 avocados per treatment).
[y]In the rating system for decay and CI, 0=none, 1=trace, 2=slight, 3=moderate, and 4=severe. Fruit with moderate and severe ratings were considered unacceptable.
10% of the rind, and detracted significantly from appearance.
[x]Acceptable fruit had good appearance, were free of moderate or severe decay and CI, and had no off-flavors.

Table 2. Quality of 'Waldin' avocados stored at 7.2°C for 25 days in various atmospheres under normal (NP) or low atmospheric pressure (LP) and then softened at 21.1° in air under NP.[z]

Storage conditions					Wt loss (%)					
Type	(mm Hg)	O_2 (%)	CO_2 (%)	Firmness before and after storage[y]	During storage	During softening	Softening time (days)	Decay (%)	Chilling injury (%)	Acceptable fruit[x] (%)
Unstored fruit				5.0	–	6.4	5.4	4	0	96
NP	760	21	0	4.0	2.2	1.3	1.2	76	100	0
NP	760	2	0	4.9	1.1	4.9	5.1	100	100	0
NP	760	2	10	5.0	1.1	4.9	5.0	4	4	92
LP	91	2	0	4.6	2.2	2.9	3.2	64	100	0
LP	91	2	10	5.0	3.1	3.8	3.7	0	0	100

[z]Each figure is the mean for 25 avocados.
[y]In the rating system for firmness, 5=hard, 4=firm, 3=firm ripe, 2=soft ripe, and 1=overripe.
[x]Acceptable fruit had good appearance, were free of moderate or severe decay and chilling injury, and had no off-flavors.

[1]Received for publication May 14, 1976.

table. 'Waldin' avocados lost very little weight and remained firm to hard, regardless of the storage atmosphere. Weight loss during softening was proportional to the softening time. The average softening time of avocados stored at NP in 2% O_2 with or without CO_2 was similar to that of freshly-picked unstored fruit and from 1-1/3 to 4 days longer than that of fruit stored in LP with and without CO_2 and of fruit stored at NP in air. Fruit stored in LP without CO_2 often failed to soften uniformly. Weight loss and softening time for 'Waldin' avocados stored at LP in 2% O_2 were similar regardless of the presence or absence of CO_2.

Data for the principal decays, anthracnose (*Colletotrichum gloeosporioides* Penz.) and stem-end rot (*Diplodia natalensis* P. Evans), plus CI are presented in Table 3. Avocados stored at NP in 21% O_2 (air) developed more anthracnose during storage than those stored at NP or LP in 2% O_2 with or without CO_2. No stem-end rot developed during storage in any atmosphere. Avocados stored in atmospheres without CO_2 developed moderate to severe anthracnose during softening, whereas fruit stored in atmospheres with 10% CO_2 developed only a trace. The amount of stem-end rot which developed during softening was slight for avocados stored at NP in 2% O_2 without CO_2, but was zero to a trace for those stored in all other atmospheres. Black pitted areas developed in lenticels during softening of avocados stored at NP or LP in 2% O_2 chambers containing 10% CO_2. However, pitting was slight and was not considered to be objectionable to the average consumer. Tissue from the infected areas contained *Pestalotia* spp. fungus.

Avocados developed more external CI during storage in air than in other atmospheres. Avocados stored at NP or LP in atmospheres without CO_2 developed moderate to severe external and internal CI, whereas fruit stored in atmospheres with 10% CO_2 developed a trace of external CI and no internal CI.

Table 3. Decay and chilling injury (CI) of 'Waldin' avocados stored at 7.2°C for 25 days in various atmospheres under normal pressure (NP) or low atmospheric pressure (LP) and then softened at 21.1° in air under NP.[z]

Storage conditions				Decay index[y]				CI Index[y]		
				After storage		After softening		After storage	After softening	
Type	(mm Hg)	O_2 (%)	CO_2 (%)	Anth[x]	SER[w]	Anth	SER	External CI	External CI	Internal CI
Unstored fruit				–	–	0.1	0.1	–	0.0	0.0
NP	760	21	0	1.5	0.0	3.2	0.0	0.8	2.6	4.0
NP	760	2	0	0.0	0.0	3.0	2.0	0.0	4.0	1.4
NP	760	2	10	0.5	0.0	1.0	0.0	0.0	0.7	0.0
LP	91	2	0	0.1	0.0	2.7	0.3	0.1	3.9	3.7
LP	91	2	10	0.3	0.0	0.8	0.0	0.0	0.4	0.0

[z]Each figure is the mean for 25 avocados.

[y]In the rating system for decay and CI, 0=none, 1=trace, 2=slight, 3=moderate, and 4=severe. Fruit with moderate and severe ratings were considered unacceptable.

[x]Anth=anthracnose.

[w]SER=stem-end rot.

Our results do not support the conclusions of others that avocados can be stored successfully at LP (2). The CO_2 requirement in our LP system for acceptable storage of avocados is in agreement with our earlier finding that CO_2 is essential in our CA system (4, 6). However, the addition of CO_2 does not make the LP system superior to the CA system, but simply makes the 2 systems comparable for quality maintenance of avocados. Relative humidity does not appear to be a factor since the acceptability values of avocados stored under LP at relative humidities of 80–85% and 98–100% were not significantly different (data not shown). Whether industry should use an LP or a CA facility will depend upon which is most economical. The fact that LP, but not CA, can be used to extend the normal storage life of limes (7) provides an advantage for the LP system.

Literature Cited

1. Burg, S. P. 1967. Method for storing fruit. *U.S. Pat.* 3,333,967.
2. ——————. 1975. Hypobaric storage and transportation of fresh fruits and vegetables. p. 172-188. *In* Postharvest biology and handling of fruits and vegetables, The AVI Publishing Co., Inc., Westport, CT.
3. —————— and W. Hentschel. 1974. Low pressure storage of metabolically active matter with open cycle refrigeration. *U.S. Pat.* 3,810,508.
4. Hatton, T. T., Jr. and W. F. Reeder. 1965. Controlled atmosphere storage of Lula avocados–1965 tests. *Proc. Caribbean Region Amer. Soc. Hort. Sci.* 9:152-159.
5. Spalding, D. H. and W. F. Reeder. 1972. Quality of 'Booth 8' and 'Lula' avocados stored in a controlled atmosphere. *Proc. Fla. State Hort. Soc.* 85:337-341.
6. —————— and ——————. 1975. Low-oxygen and high-carbon dioxide controlled atmosphere storage for control of anthracnose and chilling injury of avocados. *Phytopathology* 65:458-460.
7. —————— and ——————. 1976. Low pressure (hypobaric) storage of limes. *J. Amer. Soc. Hort. Sci.* 101:367-370.

HortScience 11(5):492–493. 1976.

The Relationship between Pistillate Flower Development and Air Temperature in 'Western' Pecan[1]

F. B. Matta[2], D. T. Sullivan[3], and F. B. Widmoyer[3]
Department of Horticulture, New Mexico State University, Las Cruces, NM 88001

Additional index words. Carya illinoensis, heat units

Abstract. **Six stages of floral development were identified and related to air temperature in *Carya illinoensis* (Wang.) K. Koch, cv. Western. Initiation (the first microscopically visible evidence of floral primordia) was detected on April 4, 1973, after an accumulation of 537 heat units. On April 10 a total of 598 heat units were accumulated when 93% of the buds sampled had initiated pistillate flowers. Floral development occurred normally, uniformly, and in concert with the heat units accumulated.**

In practically all fruit and nut crops, a certain number of heat units are required in the spring to stimulate growth and fruiting (assuming that dormancy requirements have been met). Therefore, it may be possible to accurately predict stages of flower development through the use of heat units (air temp). This prediction has advantages to the research worker and the grower in planning spray schedules.

This study was undertaken to determine the relationship between flower development and air temp. Heat units were calculated by subtracting a base temp of 40°F (4.4°C) from the average of the daily maximum and daily minimum temp (the base temp is assumed to be that at which active plant growth commences). These units were accumulated daily at each stage of flower development starting Jan. 1. Flowering stages identified for use in this study are shown in Fig. 1. Plant materials used were collected from 30 year-old 'Western' trees in a commercial orchard

[1]Received for publication March 25, 1976. Agricultural Experiment Station, New Mexico State University, Las Cruces, Journal No. 555.

[2]Present address: Texas A&M University, Horticulture Section, College Station, TX 77840.

[3]Professor of Horticulture, New Mexico State University.