

developed less decay during storage than that harvested and packed in February. Preharvest growing conditions appear to influence the postharvest holding quality of Florida lettuce. In test 8, the holding quality of lettuce was excellent, as shown by the rating for decay and the percentage of retail trim. Even after 14 days' storage at 36°F and 5 additional days at 50°F, decay was nil. This lettuce was harvested in late April and had the lowest average box weight and the lowest rating for crushing and bruising. In tests 6 and 8, the lettuce would have arrived in excellent condition in export markets, assuming that temperatures were maintained at 36°F during transit. However, the lettuce in tests 1 and 4 would not have arrived at export markets in good condition. These tests indicate that the holding quality of Florida lettuce varies considerably during the season, but that certain factors affecting holding quality can be controlled. Lettuce should not be overpacked into the fiberboard boxes; overpacking results in excessive crushing and bruising, which may lead to decay during storage.

Literature Cited

1. Beraha, L., and W. F. Kwolek. 1975. Prevalence and extent of eight market disorders of western-grown head lettuce during 1973 and 1974 in the greater Chicago, Illinois area. *Plant Dis. Rptr.* 59:1001-1004.
2. Bush, P. 1981. Antle's palletization of naked lettuce keeps step

- with industry aims. *The Packer*. 87:8B, 10B.
3. Florida Department of Agricultural and Consumer Services. 1981. *Florida Agricultural Statistics—Vegetable Summary*. 72 pp.
4. Harvey, J. M., J. K. Stewart, E. A. Atrops, and M. J. Ceponis. 1961. Field trimming of lettuce—effects on package weight and market quality. U.S. Dept. Agr. Mark. Serv. MRR 497. 9 pp.
5. Hinsch, R. T., and R. E. Rij. 1980. Mechanical damage and losses to crisphead lettuce during marketing. U.S. Dept. Agr., Sci. & Educa. Admin. AAT-W-9. 16 pp.
6. ———, and ———. 1980. Physical injury to crisphead lettuce during box closing. *HortScience* 15:657-658.
7. ———, ———, and R. F. Kasmire. 1981. Transit temperatures of California iceberg lettuce shipped by truck during hot summer months. U.S. Dept. Agr. MRR 1117. 5 pp.
8. Kader, A. A., W. J. Lipton, and L. L. Morris. 1973. Systems for scoring quality of harvested lettuce. *HortScience* 8:408-409.
9. Lipton, W. J., and W. R. Barger. 1965. Market quality of head lettuce in relation to delays between harvest and precooling and temperature after cooling. U.S. Dept. Agr. ARS 51-5. 14 pp.
10. Lutz, J. M., and R. E. Hardenburg. 1968. The commercial storage of fruits, vegetables, florist and nursery stock. U.S. Dept. Agr. Handb. 66. 94 pp.
11. Stewart, J. K., M. J. Ceponis, and C. M. Harris. 1967. Market quality of film-wrapped and naked-packed head lettuce. U.S. Dept. Agr. ARS 51-11. 8 pp.
12. Rij, R. E., R. H. Hinds, Jr., R. T. Hinsch, and C. M. Harris. 1976. Current practices and trends in marketing western iceberg lettuce in relation to other produce. U.S. Dept. Agr., Agr. Res. Serv. MRR 1052. 9 pp.
13. U.S. Department of Agriculture, Foreign Agriculture Service, Foreign Market Development. U.S. exports of fresh vegetables. Fact Sheet. May 1981. 1 p.

Proc. Fla. State Hort. Soc. 94:299-301. 1981.

INJURY TO AVOCADOS BY INSUFFICIENT OXYGEN AND EXCESSIVE CARBON DIOXIDE DURING TRANSIT¹

D. H. SPALDING
 USDA, S & E, ARS,
 Subtropical Horticulture Research Unit,
 13601 Old Cutler Road, Miami, FL 33158

F. J. MAROUSKY
 USDA, S & E, ARS,
 European Marketing Research Center,
 Rotterdam, The Netherlands

Additional index words. modified atmospheres, *Persea americana*.

Abstract. European receivers have complained of injury to avocados (*Persea americana* Miller) shipped by surface transport from the United States. The injury was reported only in fruit from containers that had been charged with a modified atmosphere prior to shipment. Injury to fruit was apparent on arrival in Europe as regular to irregular areas of brown discoloration of the rind. Underlying flesh was not discolored and the fruit were still firm to hard. The flesh of some fruit deteriorated during softening and had a fermented odor. Similar injury to avocados developed during laboratory storage in atmospheres of low-oxygen (0.5%) and high-carbon dioxide (25%).

During the 1980 avocado marketing season complaints of injury to avocados shipped to Europe from California and Florida in refrigerated containers (seavans) were received by USDA personnel in the Netherlands and Florida.

¹The authors express their thanks and appreciation for the technical assistance of Mr. William F. Reeder.

In each instance of fruit injury the container was found to have been charged before shipment with a mixture of oxygen (O₂), carbon dioxide (CO₂) and inert nitrogen (N₂) designed to decrease the rate of respiration and extend the storage life. The use of this system of modified atmosphere (MA) has been reviewed by Lipton (6). Once the initial atmosphere modification has been made, further changes in O₂ and CO₂ concentrations depend on the respiration rate of the commodity, the temperature and tightness of the container, and the time in transit. Unlike a controlled atmosphere (CA) system, the MA is not controlled and no adjustments are made during transit to maintain a particular atmosphere. The MA service as provided by commercial sources is designed to supplement the benefits of refrigeration and is presently most widely used for lettuce shipments (4).

Avocados are not injured when held in an atmosphere containing 1% O₂ (5), but are very sensitive to O₂ deficiency (1). In this paper, we present evidence suggesting that the rind injury which occurred in the commercial MA shipments to Europe could have been caused by insufficient O₂ or a combination of insufficient O₂ and excessive CO₂.

Materials and Methods

Avocados, obtained from a local packinghouse in Miami, Florida, were randomized into similar lots and placed in 5-gallon (18.9-liter) widemouth glass jars. Ten fruit of a given cultivar were placed in each jar together with 1 liter of water. Two jars were placed in series when more than 1 cultivar was used. The lid of each jar was fitted with a teflon gasket, a fitting for gas sampling, and a copper tubing inlet and outlet for gas flow. In a test with 'Simmonds' and

'Nadir' avocados, the jars were sealed, placed at 55°F (12.8°C) and changes in the O₂ and CO₂ contents of air and a MA (6% O₂ + 14% CO₂) were followed for 10 days. In another test a flow through system was used with the following controlled atmospheres (CA): 21% O₂ + 0% CO₂ (air), 0.5% O₂ + 25% CO₂, 0.5% O₂ + 0% CO₂, and 21% O₂ + 25% CO₂. A paper bag containing ca. 1 lb. (454 g) of lime was added to jars in which we wanted to absorb all CO₂. Atmospheres, except ordinary air, were obtained by mixing N₂ with O₂ and/or CO₂ and pumping the mixture through the water in the jars to produce a relative humidity of ca. 98-100%. The flow rate through the jars was adjusted to 250 ml/min to provide 1 complete atmospheric exchange per hour.

Atmospheres were monitored daily using standard gas chromatographic techniques. A gas chromatograph was used with a thermal conductivity detector, a 'Porapak N' column for CO₂, a molecular sieve column for O₂, and helium as a carrier gas at 60 ml/min. The CA tests were run at 45°F (7.2°C) for 2 weeks with 'Lula' avocados and at 55°F (12.8°C) for 10 days with 'Simmonds' and 'Nadir' avocados. Avocados were removed from the jars, examined for injury, and then held at 70°F (21°C) for up to 1 week and checked for softening and internal injury. Rind injury was rated on a scale of 0 to 4 with 0 = no injury, 1 = trace (less than 2% of surface area affected), 2 = slight (2 to 10%), 3 = moderate (11 to 20%), and 4 = severe (21 to 100%).

Results and Discussion

Injury to Fruit in Commercial Shipments. Some shipments of 'Hass' and 'Fuerte' avocados from California and 'Booth 8' avocados from Florida treated with MA arrived in Europe with injured fruit. The injury varied from small spots to brown discolored areas covering 25-40% of the rind. The injury was sometimes concentrated in the stem-end area of the fruit (Fig. 1A). The margins of the injury were generally sharp. Injury was confined to the rind and the underlying pulp generally looked normal. However, in one shipment of injured 'Booth 8' avocados, the fruit softened normally in 6 days at 70°F (21°C), but the pulp under injured areas was softer than under noninjured areas. In another shipment of 'Booth 8' avocados, differences were noted between the injury on small and large sizes. The small fruit were more severely injured and the discolored areas more sunken than on larger fruit. The interior pulp on small fruit, but not large, was deteriorated and had a pronounced odor of fermented alcohol indicative of anaerobic respiration. The injured areas, unlike decayed areas, did not increase in size during ripening. The symptoms of injury to fruit shipped under MA were similar to symptoms which developed during laboratory storage of 'Booth 8' avocados in a CA of 0.3% O₂ and 0% CO₂ for 10 days at 10°C (50°F) (Spalding and Reeder, unpublished) (Fig. 1B).

All of the commercial containers in which injury occurred registered temperatures of 74°F (23.3°C) or higher during the first 36-48 hours after the container was charged with a MA. In a typical case the recorder showed that the temperature in the container of 'Booth 8' avocados went from a high of 74°F to 40°F (4.4°C) in 2 days. However, some shipments had initial temperatures higher than 74°F. The respiration of avocados at 77-80°F (25-27°C) can range from 6 to 15 times that at 40°F (2). The initial high temperature results in faster depletion of O₂ and buildup of CO₂ than at lower temperatures. Precooling and fast transfer to refrigerated trucks and seavan containers can help prolong the life of the fruit by keeping respiration rates low.

Atmosphere Changes in Sealed Jars of Avocados. The atmospheres in sealed jars containing 'Simmonds' avocados

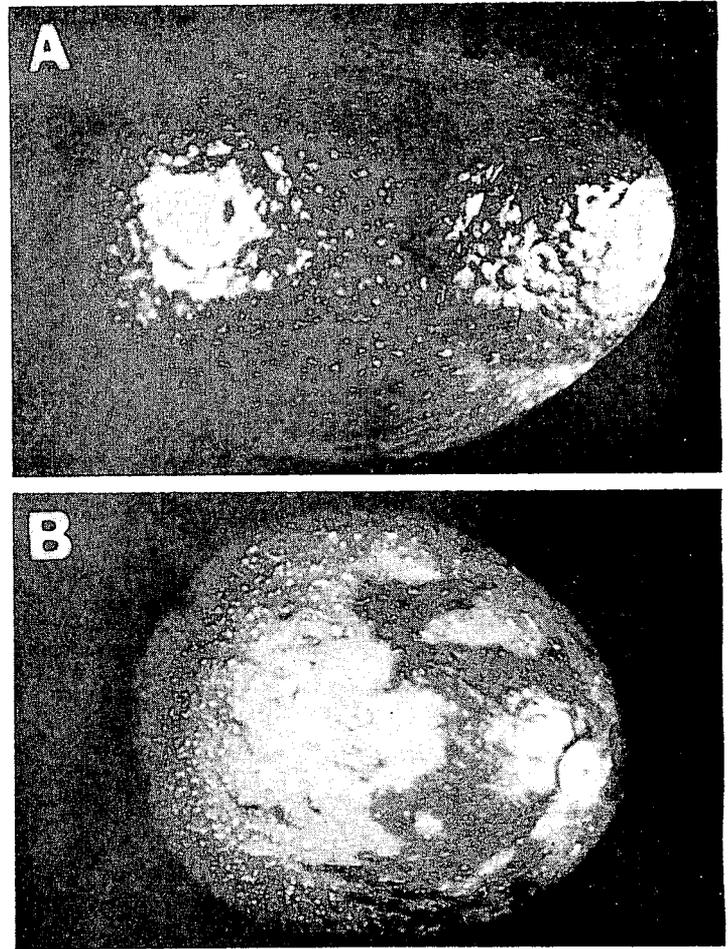


Fig. 1. A. 'Booth 8' avocado with brown regularly-shaped area of injured rind tissue around the stem-end which developed in 2 weeks at ca. 40°F (4.4°C) in a commercial container with a modified atmosphere. B. 'Booth 8' avocado with brown irregularly-shaped areas of injured rind tissue which developed in 10 days at 50°F (10°C) and 98-100% relative humidity in a laboratory chamber with a controlled atmosphere of 0.3% O₂ and 0.0% CO₂.

in an initial atmosphere of either 6% O₂ + 14% CO₂ (simulated MA) or 21% O₂ + 0% CO₂ (air) at 55°F (12.8°C) and 98-100% relative humidity showed a marked decrease in O₂ and increase in CO₂ within 24 hours (Table 1). The

Table 1. Changes in the oxygen and carbon dioxide concentrations of a modified atmosphere or normal air in sealed jars containing 'Simmonds' avocados during 10 days at 55°F (12.8°C) and 98-100% relative humidity.

Time (days)	Modified atmosphere		Air	
	O ₂ (%)	CO ₂ (%)	O ₂ (%)	CO ₂ (%)
0	6.3	13.9	21.0	0.0
1	0.6	19.6	8.6	10.3
2	0.6	23.1	2.2	19.0
3	0.5	32.8	1.0	24.4
5	0.6	44.2	0.9	39.8
6	0.3	53.1	0.7	46.7
7	0.3	54.5	0.7	50.3
8	0.2	56.1	0.7	54.7
9	0.2	58.2	0.5	56.3
10	0.3	59.3	0.5	57.5

high respiration rate of the avocados at 55°F together with the almost complete absence of leakage of fresh air into the sealed jars are responsible for the rapid change in O₂ and CO₂ concentrations. The O₂ content in the jar with an

initial MA dropped below 1% in less than 24 hours, whereas the CO₂ content rose to ca. 20%. The O₂ content in the sealed jar with an initial atmosphere of normal air dropped to less than 1% in 5 days, whereas CO₂ increased to over 20% in 3 days. Avocados are relatively tolerant of high CO₂ concentrations; for example, Brooks *et al.* (3) reported that atmospheres averaging up to 50% CO₂ at 40-50°F (4.4-10.0°C) for 2 days caused no injury and improved the flavor. All the 'Simmonds' avocados were hard on removal from the sealed jars and had developed brown irregular areas of rind injury. Similar results and injury (data not shown) were obtained with 'Nadir' avocados stored in air, but in the simulated MA with an initial 6% O₂ and 13% CO₂, no injury developed since the leakage into the container apparently was sufficient to keep the O₂ content from dropping below 1% and the CO₂ content from rising above 29%. Maintenance of avocado quality would be best if the MA could be stabilized in the range of 1-2% O₂ and 7-10% CO₂ (5, 7).

Injury in Laboratory CA Tests. In tests with 'Lula' avocados, symptoms of rind injury appeared first in fruit held only 3 days in 0.5% O₂ + 25% CO₂, and was but trace to slight in 0.5% O₂ + 0% CO₂, and absent in 21% O₂ + 25% CO₂ and in the air control. Fruit from all atmospheres were hard after 2 weeks at 45°F (7.2°C). Rind injury was most severe in 'Lula' avocados held in 0.5% O₂ + 25% CO₂ and appeared as brown or gray areas over the entire fruit surface (Table 2). Injury to 'Lula' avocados was slight

Table 2. Comparative phytotoxicity of four controlled atmospheres to fruit of three avocado cultivars during simulated transit.^z

Atmosphere		Index of Injury ^y		
O ₂ (%)	CO ₂ (%)	'Lula'	'Nadir'	'Simmonds'
21.0	0.0	0.0	0.0	0.0
0.5	0.0	1.8	1.2	0.1
0.5	25.0	4.0	0.9	1.4
21.0	25.0	0.2	0.0	0.0

^z'Lula' avocados were stored at 45°F (7.2°C) for 14 days and 'Nadir' and 'Simmonds' avocados at 55°F (12.8°C) for 10 days.

^yInjury was rated as 0 (none), 1 (trace), 2 (slight), 3 (moderate), and 4 (severe).

in 0.5% O₂ + 0% CO₂, trace in 21% O₂ + 25% CO₂, and absent in air. Results with 'Nadir' and 'Simmonds' avocados confirmed that of the atmospheres tested the combination of 0.5% O₂ with 25% CO₂ caused the most injury, 0.5% O₂ without CO₂ generally caused less injury than with CO₂, and 21% O₂ with 25% CO₂ and air caused no injury. Internal condition of avocados was checked by cutting all fruit after holding them for 1 week at 70°F (21°C) after removal from the CA chambers. Avocados held in 0.5% O₂ with or without 25% CO₂ developed moderate to severe internal injury and were not edible. Avocados held in 21% O₂ with 25% CO₂ or in air did not develop internal injury and were edible.

The laboratory results indicate that symptoms similar to those encountered in MA shipments to Europe can be produced by exposure of avocados to low-O₂ (less than 1%) or a combination of low-O₂ and high-CO₂ (25% or higher). However, no atmosphere analyses were made of the commercial containers in which injured avocados were found by receivers in Europe. Once the container is opened and the damage found, it is too late to obtain an atmosphere sample. Greater care is needed to ensure proper precooling to keep respiration low during transit and, if a MA is used, more care must be taken to assure that ventilation is sufficient to avoid the state of insufficient O₂ and excessive CO₂ that can injure the avocados.

Literature Cited

1. Biale, J. B. 1941. The climacteric rise in respiration rate of the Fuerte avocado fruit. *Proc. Amer. Soc. Hort. Sci.* 39:137-142.
2. ———. 1960. Respiration of fruits. *Encyc. Plant Physiol.* 12:536-592.
3. Brooks, C., C. O. Bratley, and L. P. McColloch. 1966. Transit and storage diseases of fruits and vegetables as affected by initial carbon dioxide treatments. U. S. Dept. of Agric. Tech. Bul. 519. 24 p.
4. Hardenburg, R. E. 1978. Vegetables. In "ASHRAE Handbook and Product Directory", Applications Volume: 34.1-34.18.
5. 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.
6. Lipton, W. J. 1975. Controlled atmospheres for fresh vegetables and fruits—why and when. In "Postharvest Biology and Handling of Fruits and Vegetables", AVI, Westport, CT, 172-188.
7. Spalding, D. H., and W. F. Reeder. 1975. Low-oxygen high-carbon dioxide controlled atmosphere storage for control of anthracnose and chilling injury of avocados. *Phytopathology* 65:458-460.

Proc. Fla. State Hort. Soc. 94:301-303. 1981.

TOLERANCE OF FLORIDA 'MARSH' GRAPEFRUIT TO METHYL BROMIDE FUMIGATION AND COLD STORAGE COMBINATION TREATMENTS EFFECTIVE AGAINST THE CARIBBEAN FRUIT FLY

C. A. BENSCHOTER
 USDA, Agricultural Research Service,
 Subtropical Horticulture Research Unit
 13601 Old Cutler Road, Miami, FL 33158

Additional index words. *Citrus paradisi*, *Anastrepha suspensa*, decay, peel injury, phytotoxicity.

Abstract. Early season grapefruit harvested in October was injured by fumigation with methyl bromide (MB) for

2 hr at 24 or 32 g/m³, followed by storage for 3 weeks at 45°F (7.2°C) or 50°F (10°C) respectively. Midseason (Jan) and late fruit (Apr) suffered no injury. Decay from all treatments was negligible in early fruit but increased as the season progressed. The peel injury to early fruit and increased decay in mid- and late-season fruit make these treatments questionable for Florida grapefruit. When fruit was fumigated with 32 or 40 g/m MB and then stored at 60°F (15.6°C) for 3-4 weeks, early fruit sustained no peel injury and had only a 0.4-3.2% increase in decay over non-treated lots. The corresponding values for mid- and late season fruit were: 0-12.0% peel injury, 0% decay, and 0% peel injury, 0% decay, respectively. Two hard freezes ca. 2 weeks prior

¹The author is indebted to the Florida Dept. of Citrus for the grapefruit used in this study.

Proc. Fla. State Hort. Soc. 94: 1981.