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INJURY TO AVOCADOS BY INSUFFICIENT OXYGEN AND EXCESSIVE CARBON DIOXIDE DURING TRANSIT[1]

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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 bown 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.

In each instance of fruit injury the container was found to have been charged before shipment with a mixture of oxygen. (O_2), carbon dioxide (CO_2) and inert nitrogen (N_2) 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 O_2 and CO_2 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% O_2 (5). but are very sensitive to O_2 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 O_2 or a combination of insufficient O_2 and excessive CO_2.

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 capper 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 O_2 and CO_2 contents of air and a MA (6% O_2 + 14% CO_2) were followed for 10 days. In another test a flow through system was used with the following controlled atmospheres (CA): 21% O_2 + 0% CO_2 (air), 0.5% O_2 + 25% CO_2, 0.5% O_2 + 0% CO_2, and 21% O_2 + 25% CO_2. A paper bag containing ca. l lb. (454 g) of lime was added to jars in which we wanted to absorb all CO_2. Atmospheres, except ordinary air, were obtained by mixing N_2 with O_2 and/or CO_2 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 Chromatographie techniques. A gas Chromatograph was used with a thermal conductivity detector, a 'Porapak N' column for CO_2, a molecular sieve column for O_2, 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 non-injured 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% O_2 and 0% CO_2 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 O_2 and buildup of CO_2 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.

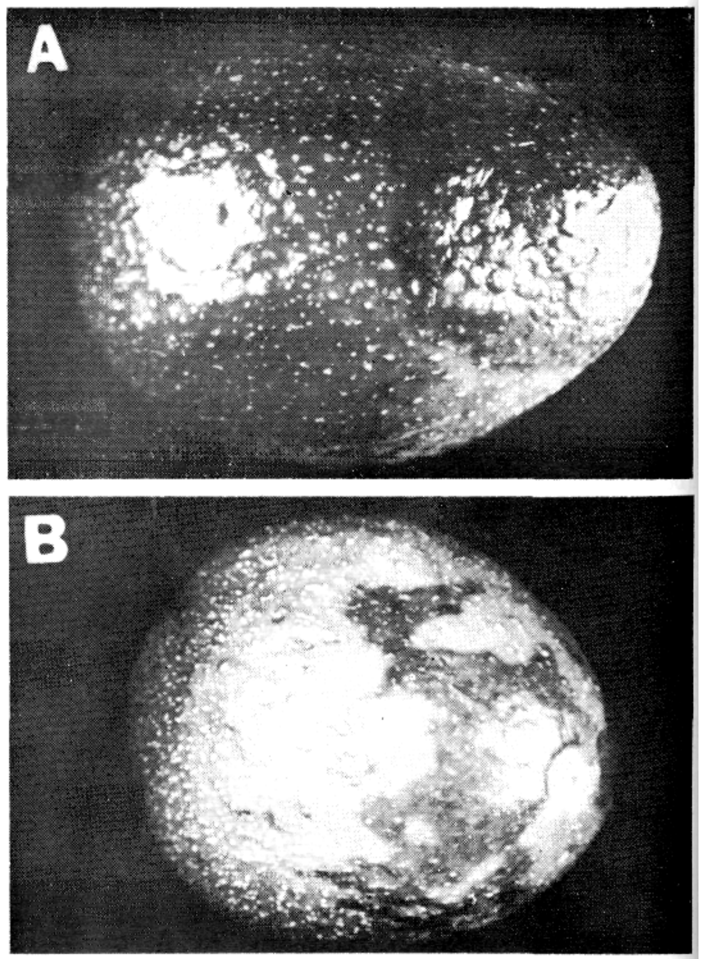

Fig. 1. A. 'Booth 8' avocado with brown regularly-shaped area of injured rind tissue around the stem-end which developed in 2 weeks at ca. 40°F (4.4°C) in a commercial container with a modified atmosphere. B. 'Booth 8' avocado with brown irregularly-shaped areas of injured rind tissue which developed in 10 days at 50°F (10°C) and 98-100% relative humidity in a laboratory chamber with a controlled atmosphere of 0.3% O_2 and 0.0% CO_2.

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 O_2 (%)	CO_2 (%)	Air 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

Atmosphere Changes in Sealed Jars of Avocados. The atmospheres in sealed jars containing 'Simmonds' avocados in an initial atmosphere of either 6% O_2 + 14% CO_2 (simulated MA) or 21% O_2 + 0% CO_2 (air) at 55°F (12.8°C) and 98-100% relative humidity showed a marked decrease in O_2 and increase in CO_2 within 24 hours (Table 1). The 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 O_2 and CO_2 concentrations. The O_2 content in the jar with an initial MA dropped below 1% in less than 24 hours, whereas the CO_2 content rose to ca. 20%. The O_2 content in the sealed jar with an initial atmosphere of normal air dropped to less than 1% in 5 days, whereas CO_2 increased to over 20% in 3 days. Avocados are relatively tolerant of high CO_2 concentrations; for example, Brooks *et al.,* (3) reported that atmospheres averaging up to 50% CO_2 at 40-50°F (4.410.0°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% O_2 and 13% CO_2, no injury developed since the leakage into the container apparently was sufficient to keep the O_2 content from dropping below 1% and the CO, content from rising above 29%. Maintenance of avocado quality would be best if the MA could be stabilized in the range of 1-2% O_2 and 7-10% CO_2 (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% O_2 + 25% CO_2 and was but trace to slight in 0.5% O_2 + 0% CO_2, and absent in 21% O_2 + 25% CO_2 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% O_2 + 25% $C0_2$ and appeared as brown or gray areas over the entire fruit surface (Table 2). Injury to 'Lula' avocados was slight in 0.5% O_2 + 0% CO_2, trace in 21% 0_2 + 25% CO_2, and absent in air. Results with 'Nadir' and 'Simmonds' avocados confirmed that of the atmospheres tested the combination of 0.5% O_2 with 25% CO_2 caused the most injury, 0.5% O_2 without CO_2 generally caused less injury than with CO_2, and 21% O_2 with 25% CO_2 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% O_2 with or without 25% CO_2 developed moderate to severe internal injury and were not edible. Avocados held in 21% O_2 with 25% CO_2 or in air did not develop internal injury and were edible.

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.
[y]Injury was rated as 0 (none), 1 (trace), 2 (slight), 3 (moderate), and 4 (severe).

The laboratory results indicate that symptoms similar to those encountered in MA shipments to Europe can be produced by exposure of avocados to low-0_2 (less than 1 %) or a combination of low-O_2 and high-CO_2 (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 O_2 and excessive CO_2 that can injure the avocados.

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