

CURRENT STATUS OF CONTROLLED ATMOSPHERE STORAGE OF FOUR TROPICAL FRUITS

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Abstract

Benefits of laboratory controlled atmosphere (CA) storage of various tropical fruits vary from none to excellent. Mangos (*Mangifera indica* L.) and papayas (*Carica papaya* L.) show none to slight benefit from CA's tested. 'Tahiti' ('Persian') limes (*Citrus latifolia* Tanaka) usually develop severe injury and decay in low-O₂, atms. Avocados (*Persea Americana* Mill.) benefit greatly by storage in a CA of 2% O₂, + 10% CO₂. Quality is maintained and normal storage life is extended in CA. Chilling injury of avocados at 45°F (7.2°C) is inhibited in an atm of 2% O₂ and 10% CO₂. The first commercial CA storage of avocados (mainly 'Lula') was accomplished successfully in Florida during the 1973-74 season.

Relatively little research has been done on the controlled atmosphere (CA) storage of tropical fruits compared with the vast amount of research done with temperate fruits. The challenge to researchers is to find storage conditions that will place the fruit in a state of "suspended animation" in which life processes are maintained but harmful deteriorative processes are retarded. The finding of such conditions could extend the normal marketing season and allow the holding of excess produce during times when markets are oversupplied.

The susceptibility of tropical fruits to chilling injury means that refrigeration cannot be used to full capacity but temp must be held close to 55°F (12.8°C), at which aging, ripening and decay can soon cause destruction of stored fruit*. Where high non-chilling temps must be used in storage chambers, the use of CA serves to supplement the refrigeration and further slow the metabolic rate of the fruit and thereby extend the normal storage life. The CA's employed normally involve decreasing the oxygen (O₂) concn below that in air (21% O₂), increasing the carbon dioxide (CO₂) concn (air = 0.03%), or both. Such atm changes may markedly reduce respiration and delay the climacteric and associated: ripening, changes. (4).

Avocados

The success of CA storage of apples stimulated CA research with a wide variety of fruits and vegetables in the hope that similar benefits could be achieved. Unfortunately, most trials have been disappointing, or benefits were not great enough to stimulate commercial interest. Work with avocados, however, has been most rewarding. Early studies with 'Fuerte' avocados showed that within the range of 2.5 to 21% O₂ concn, the time required to reach the respiration climacteric peak was extended in proportion to the

decrease in O₂ concn (3). The climacteric could also be delayed by storage-in 10% CO₂ with 21% O₂ (21). The climacteric represents the large burst of metabolic activity, measured in terms of respiration that precedes ripening in certain fruits. The ability to delay the ripening process using CA provided a sound basis for the CA trials run with Florida avocado cvs. CA studies over the past 10 years have shown that use of 2% O₂, with 10% CO₂ and the remainder nitrogen (N₂) doubles the normal storage life of 'Lula', 'Booth 8', and 'Fuerte' avocados at 45°F (7.2°C) (5, 9, 10, 12, 13, 16). 'Lula' avocados were stored satisfactorily for less than 3 weeks in air and 6 to 8 weeks in CA; 'Booth 8' for less than 3 weeks in air and between 3 and 6 weeks in CA; and 'Fuerte' for less than 3 weeks, in air and 6 weeks in CA. Such results suggest the possibility of extending the Florida avocado season throughout the year.

Use of CA for storage of avocados helps keep them in the firm mature-green stage at which they are resistant to the anthracnose fungus, *Colletotrichum gloeosporioides* Penz. the major cause of spoilage during storage and marketing. Use of the recommended CA also retards development of chilling injury and allows storage at 45 °F rather than a higher temp. At a higher temp the processes of ripening and anthracnose decay proceed at faster rates. Recent work with the cold-sensitive 'Waldin' and 'Fuchs' avocados confirmed the report that 10% CO₂ suppressed chilling injury in 'Taylor' avocados (20) and demonstrated further that the combination of the 2% O₂ with the 10% CO₂ was much more effective than either low-O₂ or high CO₂ alone (18). These results indicate that even a cold-sensitive cv. such as 'Waldin', with a normal storage life of 2 weeks (9), could be held in CA storage for 4 weeks at 45 °F during the peak harvest period and then-marketed in an orderly manner. This procedure might avoid over-supplying markets and depressing prices.

Limes

It has become increasingly apparent during the past 10, years that CA storage is of significant benefit to only a few kinds of fruit. CA storage trials with 'Tahiti' limes have often resulted in increased injury and decay (7, 14). Quality of these limes is closely associated with unblemished general appearance and bright green color. One of the better CA's found for retention of color is 5% O₂ with 7% CO₂ (7), but limes stored in this atm often have a juice content below the minimum-allowed volume of 42% and severe decay. The low juice content is associated-with thickening of the rind and is thought to be: a symptom of low-O₂ injury (19)

Loss of green color in limes is also retarded by storage in a CA of high-CO₂ concn (14). Half of the limes stored .for 6 weeks at 50°F (10°C) in a CA of 7 or 10,% CO₂ with 21% O₂ were still, acceptably green with a normal thickness of rind and an acceptable juice content (19). However, even though use of 7 to 10% ,CO₂ is superior to ordinary air storage, recent tests have confirmed the greater effectiveness of a low pressure (hypobaric) system for storage of limes (19).

Mangos

The short season for mangos and their relatively short shelf life has re-stimulated research in several countries to develop effective methods of extending storage and preventing decay. Researchers in India (11) reported successful storage of 'Alphonso' and 'Raspuri' mangos in 7.5% CO₂. 'Alphonso' mangos were held for 5 Weeks at 48.5 °F (9.2°C) and 'Raspuri' mangos for 7 weeks at 43.5°F (6.4°C) with less than 10% loss. After storage the mangos ripened satisfactorily in 3 days with no additional losses reported. However, a ripening time of 5 to 6 days is usually required to allow sufficient time to market the fruit.

Work with Florida cvs. has not been encouraging. The best CA (5% O₂ with 5% CO₂) for storage of 'Keitt' mangos at 55 °F was not significantly better than air storage even for 3 weeks (6). Stem-end rot caused by *Diplodia natalensis* P. Evans was considered to be the principle factor limiting storage. Attempts to control stem-end rot with heated fungicide treatments applied after harvest have not been effective (17). A CA of 2% O₂, was superior to atms of 2% O₂ with 10% CO₂, 21% O₂ with 10% CO₂, or 21% O₂ (air) for storage of 'Keitt' mangos at 45°F for 3 weeks followed by softening in air at 70°F (21.1°C) (unpublished results of Spalding and Reeder). Differences between treatments were not as apparent after fruit were softened as on removal from storage. The fruit were not as attractive as ripened prestorage samples. In 'Keitt' mangos held for 6 weeks, anthracnose decay and chilling injury were severe, regardless of atm.

Attempts in Israel (15) to store mangos in a CA at 43.7°F (7°C) or 50°F resulted in severe chilling injury. An *Alternaria* sp. caused the most rot during storage.

In current laboratory tests in Israel, 'Haden' mangos are stored in a CA of 2% O₂ with 1% or 5% CO₂ for 6 weeks. The more mature mangos are stored at 50-51.8°F (10-11°C) and the less mature at a minimum of 55.4°F (13°C) to avoid chilling injury. Various fungicide treatments are under evaluation. The problem of fungal infection has not been solved and losses due to rots are still too high to make CA storage economically feasible.

Papayas

Decay is also the chief limiting factor in the storage of papayas. 'Solo' papayas stored in 10% CO₂ for 6 days at 65°F (18.3°C) developed less decay than comparable fruit stored in air or higher concns of CO₂, (1). Development of external color of papayas removed from 10% CO₂ was delayed 2 days over comparable fruit stored in air. Decay, however, developed rapidly in papayas after removal from 10% CO₂. Shelf life of papayas stored at 55°F for 6 days in 1% O₂ or for 12 days in 1.5% O₂ was slightly over 1 day longer than comparable papayas stored in air (2). Storage in CA supplemented the hot-water treatment used in Hawaii to retard development of decay in exported papayas.

In initial tests in Florida, papayas were 90% acceptable with fair appearance, zero to slight decay, and good flavor, after storage in 1% O₂ with 5% CO₂, for 3 weeks at 55°F followed by softening in air at 70°F (8). Comparable fruit stored in air were only 10% acceptable. Anthracnose (*C. gloeosporioides*) and stem-end rot (*D. natalensis*) were the primary factors limiting acceptability. Fruit from CA and air did not differ in time required

to soften at 70°F. Present production of papayas in Florida is insufficient to warrant CA storage.

Commercial CA Storage

The western hemisphere's first commercial CA storage for avocados was built by J. R. Brooks & Son, Inc. in southern Florida and placed in operation during the 1973-74 season. The 4 air-tight, 1200 bu (30 metric tons) capacity rooms were filled mainly with 'Lula' avocados in bulk bins. Rooms were run at 2% O₂ with 10% CO₂, 95% relative humidity, and 45°F. To obtain the desired atm air in the sealed room is passed at 8 ft³/min (3.8 liters/sec) through a catalytic burner (SMB Corp., Seattle, WA) using a platinum-palladium catalyst to oxidize propane. The O₂ of the air is consumed in the process, but incomplete oxidation of propane releases both CO₂ and ethylene gases. The ethylene gas can trigger ripening of the avocados if allowed to enter the CA chamber. Ethylene is eliminated by venting the atm from the catalytic burner outside the building until the temp of the burner is approx 1100°F (593°C). Ethylene is destroyed at this temp. When tests, using an ethylene analyzer, indicate that the air contains less than 0.5 ppm of ethylene, the air is admitted to the CA room. However, before admission the air is cooled to approx 125°F (51.7°C) by a mist of water sprayed from rapidly revolving nozzles. In areas having hard water, water must be softened by passage through an ion-exchange bed to avoid clogging the cooling system and causing costly "shut-downs" to descale equipment. The air enters the CA room in front of the refrigeration coil and is rapidly cooled to approx 52°F (11.1°C) by the 30 ton capacity refrigeration system. Air from the CA room is recycled through the catalytic burner until the desired O₂ concn is obtained. However, when the O₂ concn is reduced to less than approx 5%, there is insufficient O₂ to support complete combustion of propane. The temp therefore drops to approx 850°F (454.5°C) and undestroyed ethylene enters the CA room in large quantities. Incomplete combustion at low-O₂ concns can be avoided by decreasing the volume of propane to balance with the O₂ supply. Using this procedure an atm of 2 to 3% O₂, free of ethylene, can be obtained approx 8 hr after the CA room is loaded and sealed. The CO₂ concn of the room can be reduced by adding bags of lime to absorb CO₂ and keep the concn close to 10%. Final adjustment of temp of room to 45 °F is made after the catalytic burner is turned off.

A 2 degree fluctuation in the temp of a sealed CA room varies the atmospheric pressure. These pressure changes are accommodated by attaching external polyethylene bags (breather bags) to each room to permit the atm to expand and contract.

The first season the avocados were held for about 5 weeks before shipment to market. Aside from some rind discoloration (chilling injury) to avocados in rooms where the temp dropped below 40°F (4.4°C) most of the avocados were marketed in excellent condition. Under the recommended conditions, 'Booth 8' and 'Lula' avocados should store satisfactorily for 4 and 8 weeks, respectively, depending on initial condition.

Such factors as advanced maturity, delay between picking and sealing in a CA storage, preharvest frost exposure, and picking and handling wounds can reduce storage life of avocados. Care in operating CA rooms close to recommended specifications can

reduce risk. Samples should be removed periodically and ripening time and extent of decay determined. If in doubt, the room should be opened and the fruit marketed.

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