

RESULTS AND RECOMMENDATIONS ON CONTROLLED AND
MODIFIED ATMOSPHERE STORAGE AND TRANSPORT OF STONE FRUITS

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Apricots: Currently there is no known commercial use of either controlled atmospheres (CA) or modified atmospheres (MA) for storage or transport of apricots for fresh market. If precooled promptly after harvest, apricots usually can be stored 2-3 weeks in air at -0.5° to 0°C . Early research by Claypool and Allen (6) showed that 2.5% O_2 reduced the respiration rate of apricots more than an O_2 level of 5 or 10% O_2 at 4.4°C . Experimental results with CA depend on the cultivar, maturity and test conditions. California grown 'Blenheim' apricots stored at 0°C for processing kept up to 50 days in a CA of 2-3% O_2 and 2.5-3.3% CO_2 in contrast to 23 days in air (5). Compared to air-stored apricots, CA fruit had better appearance, remained firmer and more acid during storage, and retained better flavor after canning. Using higher CO_2 (5 or 10%) caused more loss of flavor than lower CO_2 . The 'Tilton' variety benefitted to a lesser degree. This use of CA storage to hold 'Blenheim' for canning in mixed-fruit salads received limited commercial trials. CA currently is not used to hold apricots for processing.

Tests in Israel with 'Canino' apricots in CA storage were not successful with either hard-ripe or ripe fruit. After 3-4 weeks at 0°C , the CA fruit had more internal browning than fruit from regular storage (11). Neither high CO_2 (3-9%) nor absence of CO_2 improved the keeping quality.

Use of polyethylene (poly) liners for storage of apricots was detrimental in South African tests (4). 'Royal' ('Blenheim') apricots stored in poly had inferior flavor and gel-breakdown, a storage disorder, which was more severe than in control fruit.

Hypobaric storage at 102 mm Hg delayed softening, delayed loss of sweetness and extended storage life to 90 days for apricots held at 0°C in tests by Salunkhe and Wu (21). The control apricots kept 53 days. Further research is needed on hypobaric storage of apricots.

CA storage of apricots for the fresh market is not recommended.

Peaches and Nectarines: Most cultivars of peaches and nectarines harvested at the firm-ripe stage can be stored about 3 weeks at 0°C and still ripen to acceptable dessert quality.

Research results on the use of CA storage to extend the life of peaches and

nectarines look very promising particularly if CA conditions are combined with an intermittent warming (IW) treatment. When stored in 1% O₂ + 5% CO₂ at 0°C some peach and nectarine cultivars retained good quality 2 to 3 times as long as those in air (1). By supplementing these CA conditions with an IW treatment, storage life can likely be extended beyond that in CA alone (2).

Several other investigators have recently reported on CA conditions that maintained peach and nectarine quality better with less internal breakdown than air storage. Munoz-Delgado and his coworkers (18) reported that their best results were obtained when 'Confrente' peaches were stored in 1% O₂ + 5% CO₂ at 0°C. Kajiura (14) reported that the optimum storage atmosphere for 'Okubo' peaches seemed to be 3% O₂ + 3% CO₂ at 0° to 1°C.

For nectarines, Olsen and Schomer (19) found the most favorable atmosphere to be either 2.5% or 21% O₂ in combination with 5% CO₂ at -0.5°C. Not all recent studies have shown CA to be beneficial. Wankier et al. (27) found CA to be unsatisfactory for peach storage. However, they did not test any of the fore-mentioned atmospheres.

There is now some CA storage of 'Fay Elberta' peaches for processing, especially for freezing. The 1976 results looked promising, and California processors are planning to continue use of CA storage. The atmosphere used is 2% O₂ and 5% CO₂ at 0°C.

The degree of benefits obtained in CA appears to be affected by fruit maturity. Both Munoz-Delgado et al. (18), and Kajiura (14) indicated that their more promising results were obtained with less mature fruit. Anderson et al. (1) found that the less mature fruit (12-16 lb) tended to respond better under CA-IW conditions than the more mature fruit (8-10 lb). The matter of maturity for CA needs further testing.

Not only have research studies indicated what CA conditions may benefit peaches and nectarines but also they have pointed out some harmful conditions, such as too high CO₂ or low O₂ levels. A level of 10% CO₂ has caused injuries or off-flavors in both peaches and nectarines (14,19). Levels of 0 and 0.25% O₂ at 0°C (1) and levels of 0 and 1% O₂ at 4°C (13) have injured peaches. External low O₂ injuries have been described as skin browning on peaches and as black pitting on nectarines (1). Internally such injuries were manifested as a grayish-brown breakdown or as a watery breakdown surrounding the stone (1,13). Fruit injured by low O₂ often had a fermented flavor, (1, 13) and a high ethanol content (13).

Intermittent warming may injure fruit. In early tests with IW (2 days at 18°-20°C in air after 2-3 weeks in CA at 0°C) some lots of fruit developed skin

browning, brown spotting or skin cracking (2). These types of injury can be prevented if the fruit are warmed gradually from 0° to 18°C.

Decay has been a serious problem in several of our CA tests, and Olsen and Schomer (19) noted serious decay in nectarines stored 11 weeks. Brown rot was controlled quite well in stored fruit that had been dipped in suspensions of 100 ppm benomyl (methyl 1-(butylcarbamoyl)-2-benzimidazole-carbamate) at 46°C for 2-1/2 minutes (12, 26). Other rots may occur, and treatments to control such rots are needed (2, 3).

Hypobaric storage test results with peaches have been conflicting. Salunkhe and Wu (21) reported that softening of peaches was delayed and the storage life increased from 7 to 27 days by storage in subatmospheric pressure. Kajiura (14) found that hypobaric conditions reduced mealy breakdown but did not control flesh browning and abnormal peeling. Loughheed et al. (15) cited Porritt and Woodruff as suggesting "that LPS (low pressure storage) has not proven suitable for peaches". Additional research is needed to further assess the value of hypobaric storage to extend storage life of peaches.

In Italy, some peaches are shipped to other parts of Europe in large plastic bags containing "Tectrol" atmospheres of about 2-3% O₂ with 5-7% CO₂ at 3°-4°C. The CO₂ probably helps retard ripening. Transit times range from 5-8 days.

In summary, CA storage of peaches and nectarines for fresh market is not in commercial use. Some California peaches were held in CA successfully to await processing in 1976. Laboratory results suggest that CA storage of peaches and nectarines for fresh market may be well worth considering for late varieties, at least on a pilot scale.

Plums: California now produces about 85% of all U.S. plums for fresh market, and production has increased steadily in recent years. Plums, including fresh prunes, are not adapted to long storage. Some of the better keeping plums can be stored 1 month, and Italian prunes about 2 weeks, at -0.5° to 0°C. Longer storage often results in flesh browning and abnormal flavors (16).

There is no known commercial use of CA storage or transport of plums in the U.S. Claypool and Allen (6) showed that storage in 2.5% O₂ lowered respiration appreciably more than storage in 5 or 10% O₂ at 4.4°C.

In England, Smith (25) demonstrated that 'Victoria' plums, a cultivar sensitive to low temperature, had a markedly extended storage life in 1% O₂ at 1.1°C. Storage for 4 weeks was possible because internal browning and respiration were reduced in CA. Further extension of storage to 6 weeks was possible in a CA of 1% O₂ at -0.5°C when the fruit were held 2 days at 18°C in air after the 16th day.

In Israel, Sive and Reznitsky (24) extended the storage of 'Sagiv' Italian prunes in a CA of 2% O₂ with either 2 or 5% CO₂ at 0°C. Examinations made after 40 or 70 days + 2 days at 18°C² showed good quality retention of the CA fruit. External appearance, flesh color, firmness and taste were all good for the CA fruit, whereas control fruit had serious internal breakdown.

Use of sealed poly liners to create a beneficial modified atmosphere for plums produced variable results; hence, poly generally is not used commercially. The film density, thickness, tightness of seal, storage temperature and variety may all affect the MA obtained. Each cultivar must be considered individually. Couey (7) found that 'Eldorado' plums stored in 1.5-mil poly liners held up well for 6 weeks at -0.5° to 1°C in an atmosphere averaging 7% O₂ and 7% CO₂. The benefits over air storage included less decay, and better retention of flesh color and flavor. Sealed poly extended storage life of 'Nubiana' plums beyond 5 weeks and up to 10 weeks at -0.5° to 1°C (8). The atmosphere ranged from 8-14% O₂ and 6-10% CO₂. This MA retarded softening and reduced decay over air storage. Boyes (4) in South Africa reported that poly liners retarded ripening of both 'Santa Rosa' and 'Kelsey' plums. However, internal breakdown and decay were higher than in control fruit, and some fruits were fermented. Storage life of Italian prunes packed in Washington State was not improved in sealed poly liners at 4.4°C. Browning at the pit was severe in all fruit in sealed poly-lined packs. Using perforated poly liners for prunes usually resulted in more decay.

Development of more good quality, late-season plum cultivars and storage at colder temperature (-1.1°C) has reduced the need to extend storage of early or mid-season cultivars by CA or MA.

Sweet Cherries: Cherries are very perishable and should be precooled quickly after harvest to as near 0°C as possible and held at -1° to 0°C. Their storage life is short, only about 2 weeks with good handling (16). A fungicide such as captan (n-trichloromethyl-mercapto-4-cyclohexene-1,2) is recommended to retard postharvest decay in sweet cherries. Moisture loss must be minimized so that fruit darkening will be retarded and stems kept green and turgid.

It has been known for years that sweet cherries are very tolerant of high CO₂. A common practice was to use 1,000-1,200 lb of dry ice in freight cars to create high CO₂, which would help retard decay during the 7-10 days' trip to market. This is no longer done because of the widespread use of poly liners and more rapid transport by air and truck.

For many years, poly box liners have been used in the Pacific Northwest to retard moisture loss and create a beneficial MA through product respiration. Sealed poly liners created an atmosphere averaging 9% O₂ and 6.5% CO₂, which extended the market life to 3 weeks (9, 10). The MA reduced decay, and preserved stem and fruit brightness for a longer time under usual storage and

transit conditions than air storage. An advantage is that cherries are in the MA during transit, as well as in storage. Sealed liners must be slit or torn open when the fruit are removed from refrigeration so that too low O_2 at warmer temperatures would be avoided. In California, poly liners are not recommended for sweet cherries because they increase loss from brown rot or other decays (17).

Currently commercial practice in the Northwest has changed to the use of³ folded-top poly liners which do not have to be torn open at destination. Carbon dioxide averages slightly lower in these than in sealed liners, but otherwise most of the advantages are retained.

There is now a trend to store more Pacific Northwest cherries in CA after they have been packed in film-lined boxes. Small apple CA rooms are used with an atmosphere of about 10% CO_2 with 3-21% O_2 . Schomer and Olsen (22), Porritt and Mason (20), and Singh et al. (23), all found that cherries retained slightly better appearance in CA or poly than in air. A general conclusion, however, was that the benefits from CA storage were no greater than from the use of sealed poly liners. Now that folded top, rather than sealed, liners are used and many more CA rooms are available in the area, it is likely that more cherries will be stored in CA where a CO_2 level of 10% or more can be maintained.

The longest storage life reported for 'Bing' sweet cherries is 93 days in experimental hypobaric chambers at 102 mm Hg at 0°C (21). The cherry stems stayed green only 60 days, so perhaps that is a more practical life. Hypobaric storage apparently is quite beneficial for cherries, but further research is needed on the relative value of CA and hypobaric storage.

Some sweet cherries have been shipped under "Tectrol" MA in pallet-size poly bags similar to those used for strawberries.⁴ The atmosphere added is 10-12% CO_2 , and O_2 is left fairly high at 10% or above with shipment at about 3°C. Because sweet cherries are often shipped in mixed loads, with apples or other fruit, this system of using MA may be both beneficial and practical. Published experimental evidence is lacking. In summary, some sweet cherries are being stored for fresh market and shipped commercially in controlled or modified atmospheres.

¹ Personal communications from F. Gordon Mitchell, Univ. of California, Davis, Calif., March 1977.

² Personal communication, J. Lugg, TransFRESH Corp., Salinas, Calif., March 22, 1977.

³ Personnel communication, Dr. M. Couey, USDA, Wenatchee, Washington, March 1977.

⁴ See footnote 2.

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