A SUMMARY OF CA REQUIREMENTS AND RECOMMENDATIONS FOR FRUITS OTHER THAN POME FRUITS

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General Summary

Commodity	Temperature range[1] (°C)	CA[2] % O_2	CA[2] % CO_2	Remarks[3]
Apricot	0 - 5	2 - 3	2 - 3	
Avocado	5 - 13	2 - 5	3 - 10	
Banana	12 - 16	2 - 5	2 - 5	Limited commercial use during transport
Blackberry	0 - 5	5 - 10	15 - 20	
Blueberry	0 - 5	5 - 10	15 - 20	
Cherry, sweet	0 - 5	3 - 10	10 - 15	Some commercial use within pallet covers during transport
Cranberry	2 - 5	1 - 2	0 - 5	
Fig	0 - 5	5 - 10	15 - 20	
Grape	0 - 5	2 - 5	1 - 3	Incompatible with SO_2; 5-10% CO can be used instead of SO_2
Grapefruit	10 - 15	3 - 10	5 - 10	
Kiwifruit	0 - 5	1 - 2	3 - 5	C_2H_4 must be maintained below 20 ppb.
Lemon	10 - 15	5 - 10	0 - 10	
Lime	10 - 15	5 - 10	0 - 10	
Mango	10 - 15	3 - 5	5 - 10	
Nectarine	0 - 5	1 - 2	3 - 5	
Olive	5 - 10	2 - 5	5 - 10	
Orange	5 - 10	5 - 10	0 - 5	
Papaya	10 - 15	3 - 5	5 - 10	
Peach, clingstone	0 - 5	1 - 2	3 - 5	Limited commercial use to extend canning season
Peach, freestone	0 - 5	1 - 2	3 - 5	
Persimmon	0 - 5	3 - 5	5 - 8	Limited use of MA packaging
Pineapple	8 - 13	3 - 5	5 - 10	
Plum	0 - 5	1 - 2	0 - 5	Limited use for long-term storage
Raspberry	0 - 5	5 - 10	15 - 20	Some commercial use within pallet covers during transport
Strawberry	0 - 5	5 - 10	15 - 20	Some commercial use within pallet covers during transport

[1]Usual and/or recommended range; a relative humidity of 90-95% is recommended.
[2]Specific CA combination depends on cultivar, temperature, and duration of storage.
[3]Comments about use refer to domestic marketing only; many of these commodities are shipped under modified atmospheres for export marketing.

COMMODITY: Apricot VARIETY: (if necessary) _____

OPTIMUM TEMPERATURE: -0.5° to 0°C, expected range: 0° to 5°C

MODIFIED ATMOSPHERE CONSIDERATIONS:

	REDUCED O_2	INCREASED CO_2
Beneficial level:	2 - 3%	2 - 3%
Benefits:	Delayed ripening	Firmness retention
Potential for benefit:	Moderate	Moderate
Injurious level:	< 1%	> 5%
Injury symptoms:	Off-flavor development	Loss of flavor, flesh browning
Potential for injury:	Slight to moderate	Slight to moderate
Commercial use or potential:	Very limited use on apricots destined for canning	

REMARKS: The addition of 5 - 10% CO, as a fungistat, may improve the potential for benefit from CA.

SELECTED REFERENCES:

1. Brecht, J.K., A.A. Kader, C.M. Heintz, and R.C. Norona. 1982. Controlled atmosphere and ethylene effects on quality of California canning apricots and clingstone peaches. J. Food Sci. 47:432-436.

2. Claypool, L.L. and R.M. Pangborn. 1972. Influence of controlled atmosphere storage on quality of canned apricots. J. Amer. Soc. Hort. Sci. 97:636-638.

3. Wankier, B.N., D.K. Salunkhe, and W.F. Campbell. 1970. Effects of controlled atmosphere storage on biochemical changes in apricot and peach fruit. J. Amer. Soc. Hort. Sci. 95:604-609.

COMMODITY: Avocado VARIETY: (if necessary) _____

OPTIMUM TEMPERATURE: 10°C, expected range: 5° to 13°C

MODIFIED ATMOSPHERE CONSIDERATIONS:

	REDUCED O_2	INCREASED CO_2
Beneficial level:	2 - 5%	3 - 10%
Benefits:	Delayed ripening	Delayed softening, reduced chilling injury symptoms
Potential for benefit:	Good	Good
Injurious level:	< 1%	> 15%
Injury symptoms:	Off-flavors, internal flesh browning	Skin browning, off-flavors
Potential for injury:	Moderate	Moderate
Commercial use or potential:	May be useful in reducing further softening and chilling injury symptoms on ethylene-treated avocados during transport at 5°C	

REMARKS: CO at 5 - 10% addded to CA may be useful in reducing decay problems

SELECTED REFERENCES:

1. Biale, J.B. 1942. Preliminary studies on modified air storage of the Fuerte avocado fruit. Proc. Amer. Soc. Hort. Sci. 41:113-118.

2. Hatton, T.T. and W.F. Reeder. 1972. Quality of 'Lula' avocados stored in controlled atmospheres with or without ethylene. J. Amer. Soc. Hort. Sci. 97:339-341.

3. Spalding, D.H. and F.J. Marousky. 1981. Injury to avocados by insufficient oxygen and excessive carbon dioxide. Proc. Fla. State Hort. Soc. 94:299-301.

4. 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.

5. Young, R.E., R.J. Romani, and J.B. Biale. 1962. Carbon dioxide effects on fruit respiration. II. Response of avocados, bananas, and lemons. Plant Physiol. 37:416-422.

COMMODITY: Banana VARIETY: (if necessary) _____

OPTIMUM TEMPERATURE: 14°C, expected range: 12° to 16°C

MODIFIED ATMOSPHERE CONSIDERATIONS:

	REDUCED O_2	INCREASED CO_2
Beneficial level:	2 - 5%	2 - 5%
Benefits:	Delayed ripening	Delayed ripening
Potential for benefit:	Very good	Very good
Injurious level:	< 1%	> 7%
Injury symptoms:	Dull yellow to brown skin discoloration, failure to ripen, off-flavors	Green fruit softening, undesirable texture and flavor
Potential for injury:	High	Moderate to high
Commercial use or potential:	Modified atmospheres (1 - 5% O_2 and 4 - 6% CO_2) and/or ethylene-absorbent are used commercially during long-distance transport	

REMARKS: Removal of ethylene from CA or MA transport or storage atmosphere is highly recommended for best results

SELECTED REFERENCES:

1. Broughton, W.J. and K.F. Wu. 1979. Storage conditions and ripening of two cultivars of banana. Scientia Hort. 10:83-93.

2. Liu, F.W. 1976. Storing ethylene-pretreated bananas in controlled atmosphere and hypobaric air. J. Amer. Soc. Hort. Sci. 101:198-201.

3. McGlasson, W.B. and R.B.H. Wills. 1972. Effects of oxygen and carbon dioxide on respiration, storage life, and organic acids of green bananas. Australian J. Bio. Sci. 25:35-42.

4. Quazi, M.G. and H.T. Freebairn. 1970. The influence of ethylene, oxygen, and carbon dioxide on the ripening of bananas. Bot. Gaz. 131:5-14.

5. Woodruff, R.E. 1969. Modified atmosphere storage of bananas. Proc. Nat. CA Res. Conf., Mich. State Univ., Hort. Rept. 9:80-94.

COMMODITY: Blackberry VARIETY: (if necessary) _____

OPTIMUM TEMPERATURE: -0.5 to 0°C, expected range: 0° to 5°C

MODIFIED ATMOSPHERE CONSIDERATIONS:

	REDUCED O_2	INCREASED CO_2
Beneficial level:	5 - 10%	15 - 20%
Benefits:	Reduced respiration rate	Reduced decay, firmness retention
Potential for benefit:	Moderate	Very good
Injurious level:	< 2%	> 25%
Injury symptoms:	Off-flavors	Off-flavors
Potential for injury:	Slight to moderate	Moderate
Commercial use or potential:	Limited use during transport within pallet covers	

REMARKS: Prompt cooling to near 0°C should be done before modification of the atmosphere.

SELECTED REFERENCES:

1. Brooks, C., C.O. Bartley, and L.P. McColloch. 1936. Transit and storage diseases of fruits and vegetables as affected by initial carbon dioxide treatments. USDA Tech. Bull. 519, 24 p.

2. Morris, J.R., S.E. Spayd, J.G. Brooks, and D.L. Cawthon. 1981. Influence of postharvest holding on raw and processed quality of machine-harvested blackberries. J. Amer. Soc. Hort. Sci. 106:769-775.

COMMODITY: Blueberry VARIETY: (if necessary) _____

OPTIMUM TEMPERATURE: -0.5° to 0°C , expected range: 0° to 5°C

MODIFIED ATMOSPHERE CONSIDERATIONS:

	REDUCED O_2	INCREASED CO_2
Beneficial level:	5 - 10%	15 - 20%
Benefits:	Reduced respiration rate	Reduced decay
Potential for benefit:	Moderate	Very good
Injurious level:	< 2%	> 25%
Injury symptoms:	Off-flavors	Skin browning, off-flavors
Potential for injury:	Slight to moderate	Moderate
Commercial use or potential:	Limited use during transport within pallet covers	

REMARKS: Prompt cooling to near 0°C before MA is established and maintenance of such temperature during transport are essential to reduction of postharvest losses.

SELECTED REFERENCES:

1. Ceponis, M.J. and R.A. Cappellini. 1985. Reducing decay in fresh blueberries with controlled atmospheres. HortScience 20:228-229.

2. Hruschka, W.H. and L.J. Kushman. 1963. Storage and shelf-life of packaged blueberries. USDA Mktg. Res. Rep. 612, 16 p.

COMMODITY: Cherry, sweet VARIETY: (if necessary) _____

OPTIMUM TEMPERATURE: -1° to 0°C, expected range: 0° to 5°C

MODIFIED ATMOSPHERE CONSIDERATIONS:

	REDUCED O_2	INCREASED CO_2
Beneficial level:	3 - 10%	10 - 15%
Benefits:	Firmness retention	Decay control, maintenance of fresh appearance
Potential for benefit:	Moderate	Very good
Injurious level:	< 1%	> 30%
Injury symptoms:	Skin pitting, off-flavors	Brown discoloration of skin, off-flavors
Potential for injury:	Moderate	Moderate to high
Commercial use or potential:	Increasing use during transport, especially for export marketing	

REMARKS: Elevated CO_2 may provide a satisfactory alternative to postharvest fungicides for decay control

SELECTED REFERENCES:

1. Allen, F.W. 1940. Carbon dioxide investigations: Influence of carbon dioxide atmospheres upon cherries, plums, peaches, and pears under simulated transit conditions. Proc. Amer. Soc. Hort. Sci. 37:467-472.

2. Patterson, M.E. 1982. CA storage of cherries, p. 149-154. In: D.G. Richardson and M. Meheriuk (eds.). Proc. 3rd CA Res. Conf., Timber Press, Beaverton, OR.

3. Porritt, S.W. and J.L. Mason. 1965. Controlled atmosphere storage of sweet cherries. Proc. Amer. Soc. Hort. Sci. 87:128-130.

4. Schomer, H.A. and K.L. Olsen. 1964. Storage of sweet cherries. USDA, AMS Rept. 529, 7 p.

COMMODITY: Cranberry VARIETY: (if necessary) _____

OPTIMUM TEMPERATURE: 3°C, expected range: 2° to 5°C

MODIFIED ATMOSPHERE CONSIDERATIONS:

	REDUCED O_2	INCREASED CO_2
Beneficial level:	1 - 2%	0 - 5%
Benefits:	Reduced respiration, reduced decay (?)	Firmness retention (?)
Potential for benefit:	Slight to moderate	Slight
Injurious level:	< 1%	?
Injury symptoms:	Off-flavors	?
Potential for injury:	Slight	?
Commercial use or potential:	None at this time	

REMARKS: Further research is needed to identify potential benefits and limits of tolerance to CO_2

SELECTED REFERENCES:

1. Anderson, R.E., R.E. Hardenberg, and H.C. Vaught. 1963. Controlled-atmosphere storage studies with cranberries. Proc. Amer. Soc. Hort. Sci. 83:416-422.

2. Lockhart, C.L., et al. 1971. Nitrogen gas suppresses microorganisms on cranberries in short term storage. Phytopathology 61:335-336.

3. Stark, R., F.R. Forsyth, C.L. Lockhart, and I.V. Hall. 1974. Processing quality of cranberries after extended storage in N_2 atmospheres with low and high relative humidities. Can. Inst. Sci. Technol. J. 7:9-10.

COMMODITY: Fig VARIETY: (if necessary) _____

OPTIMUM TEMPERATURE: -1° to 0°C, expected range: 0° to 5°C

MODIFIED ATMOSPHERE CONSIDERATIONS:

	REDUCED O_2	INCREASED CO_2
Beneficial level:	5 - 10%	15 - 20%
Benefits:	Reduced respiration	Decay control, firmness retention
Potential for benefit:	Moderate	Good (?)
Injurious level:	< 2% (?)	> 25% (?)
Injury symptoms:	Off-flavors (?)	Loss of flavor (?)
Potential for injury:	Moderate	Moderate
Commercial use or potential:	None at this time	

REMARKS: Further research is needed

SELECTED REFERENCES:

1. Claypool, L.L. and S. Ozbek. 1952. Some influences of temperature and carbon dioxide on the respiration and storage life of the Mission fig. Proc. Amer. Soc. Hort. Sci. 60:226-230.

COMMODITY: Grape VARIETY: (if necessary) _____

OPTIMUM TEMPERATURE: -1° to 0°C, expected range: 0° to 5°C

MODIFIED ATMOSPHERE CONSIDERATIONS:

	REDUCED O_2	INCREASED CO_2
Beneficial level:	2 - 5%	1 - 3%
Benefits:	Delayed senescence	?
Potential for benefit:	Moderate	Slight to none
Injurious level:	< 1%	> 5%
Injury symptoms:	Off-flavors	Browning of berries and stems
Potential for injury:	Slight to moderate	Moderate to high
Commercial use or potential:	Incompatible with SO_2 fumigation	

REMARKS: CO at 5 - 10% can be combined with CA to provide decay control (equally effective to SO_2)

SELECTED REFERENCES:

1. Nelson, K.E. 1969. Controlled atmosphere storage of table grapes. Proc. Nat. CA Res. Conf., Michigan State Univ., Hort. Rept. 9:69-70.

2. Uota, M. 1957. Preliminary study on storage of Emperor grapes in controlled atmospheres with and without sulfur dioxide fumigation. Proc. Amer. Soc. Hort. Sci. 69:250-253.

3. Yahia, E.M., K.E. Nelson, and A.A. Kader. 1983. Postharvest quality and storage life of grapes as influenced by adding carbon monoxide to air or controlled atmospheres. J. Amer. Soc. Hort. Sci. 108:1067-1071.

COMMODITY: Grapefruit VARIETY: (if necessary) _____

OPTIMUM TEMPERATURE: 13°C, expected range: 10°C to 15°C

MODIFIED ATMOSPHERE CONSIDERATIONS:

	REDUCED O_2	INCREASED CO_2
Beneficial level:	3 - 10%	5 - 10%
Benefits:	Delayed senescence, firmness retention	Reduced pitting and other chilling injury symptoms at 7 to 12°C, reduced stem-end breakdown
Potential for benefit:	Slight to moderate	Moderate
Injurious level:	< 3%	> 10%
Injury symptoms:	Off-flavors due to increased ethanol and acetaldehyde contents	Scald-like areas on the rind, off-flavors
Potential for injury:	Moderate	Moderate
Commercial use or potential:	Very limited use of CA + 5 to 10% CO, as a fungistat, for export shipments	

REMARKS: Prestorage treatment with 10 - 20% CO_2 for a few days may reduce chilling injury during subsequent handling at 7 to 10°C

SELECTED REFERENCES:

1. Hatton, T.T. and R.H. Cubbedge. 1977. Effects of prestorage carbon dioxide treatments and delayed storage on stem-end rind breakdown of 'Marsh' grapefruit. HortScience 12:120-121.

2. Scholz, E.W., H.B. Johnson, and W.R. Buford. 1960. Storage of Texas Red grapefruit in modified atmospheres. USDA, AMS Rep. 414, 11 p.

3. Vakis, N., W. Grierson, and J. Soule. 1973. Chilling injury in tropical and subtropical fruits. III. The role of CO_2 in suppressing chilling injury of grapefruit and avocados. Proc. Trop. Reg. Amer. Soc. Hort. Sci. 14:89-100.

4. Wardowski, W.F., L.G. Albrigo, W. Grierson, C.R. Barmore, and T.A. Wheaton. 1975. Chilling injury and decay of grapefruit as affected by thiabendazole, benomyl, and CO_2. HortScience 10:381-383.

COMMODITY: Kiwifruit VARIETY: (if necessary) _____

OPTIMUM TEMPERATURE: 0°C, expected range: 0° to 5°C

MODIFIED ATMOSPHERE CONSIDERATIONS:

	REDUCED O_2	INCREASED CO_2
Beneficial level:	1 - 2%	3 - 5%
Benefits:	Delayed ripening	Firmness retention
Potential for benefit:	Excellent	Excellent
Injurious level:	< 1%	> 7%
Injury symptoms:	Off-flavors	Internal breakdown of the flesh
Potential for injury:	Moderate	Moderate
Commercial use or potential:	Limited commercial use, expected to increase during both transport and storage	

REMARKS: CA must be established within 2 days after harvest to maximize benefits; ethylene concentration should be kept below 20 ppb to avoid accelerated flesh softening and incidence of white core inclusions.

SELECTED REFERENCES:

1. Arpaia, M.L., F.G. Mitchell, A.A. Kader, and G. Mayer. 1985. Effects of 2% O_2 and varying concentrations of CO_2 with or without C_2H_4 on storage performance of kiwifruit. J. Amer. Soc. Hort. 110:200-203.

2. Arpaia, M.L., F.G. Mitchell, G. Mayer and A.A. Kader. 1984. Effects of delays in establishing controlled atmospheres on kiwifruit softening. J. Amer. Soc. Hort. Sci. 109:768-770.

3. Harman, J.E. and B. McDonald. 1983. Controlled atmosphere storage of kiwifruit: effects on storage life and fruit quality. Acta Hort. 138:195-201.

4. McDonald, B. and J.E. Harman. 1982. Controlled-atmosphere storage of kiwifruit. I. Effect on fruit firmness and storage life. Scientia Hort. 17:113-124.

COMMODITY: Lemon VARIETY: (if necessary) _____

OPTIMUM TEMPERATURE: 13°C, expected range: 10° to 15°C

MODIFIED ATMOSPHERE CONSIDERATIONS:

	REDUCED O_2	INCREASED CO_2
Beneficial level:	5 - 10%	0 - 10%
Benefits:	Delayed senescence	Delayed loss of green color
Potential for benefit:	Moderate	Moderate
Injurious level:	< 5%	> 10%
Injury symptoms:	Off-flavors	Increased susceptibility to decay, decreased acidity
Potential for injury:	Moderate to high	Moderate to high
Commercial use or potential:	Very limited use of 5% O_2 + 5% CO_2 + 5 to 10% CO during export shipment of lemons	

REMARKS: Removal of ethylene from lemon storage facilities can reduce rate of degreening and decay incidence.

SELECTED REFERENCES:

1. Biale, J.B. 1953. Storage of lemons in controlled atmosphere. Calif. Citrog. 38:427, 436-438.

2. Grierson, W., H.M. Vines, M.F. Oberbacher, S.V. Ting, and G.J. Edwards. 1966. Controlled atmosphere storage of Florida and California lemons. Proc. Amer. Soc. Hort. Sci. 88:311-318.

3. Harding, P.R., Jr. 1964. Effect of low oxygen and low carbon dioxide combination in controlled atmosphere storage of lemons, grapefruit and oranges. Plant Dis. Reptr. 53:585-588.

4. Rygg, G.L. and A.W. Wells. 1962. Experimental storage of California lemons in controlled atmospheres. USDA, AMS Rept. 475, 11 p.

5. Wild, B.L., W.B. McGlasson, and T.H. Lee. 1977. Long term storage of lemon fruit. Food Technol. Australia 29:351-357.

COMMODITY: Lime VARIETY: (if necessary) _____

OPTIMUM TEMPERATURE: 13°C, expected range: 10° to 15°C

MODIFIED ATMOSPHERE CONSIDERATIONS:

	REDUCED O_2	INCREASED CO_2
Beneficial level:	5 - 10%	0 - 10%
Benefits:	Retarded senescence	Retarded degreening
Potential for benefit:	Moderate	Slight to moderate
Injurious level:	< 5%	> 10%
Injury symptoms:	Scald-like injury, decreased juice content	Increased susceptibility to decay
Potential for injury:	Moderate	Moderate to high
Commercial use or potential:	Very limited use of CA + 5 to 10% CO (for decay control) during marine transport	

REMARKS: Removal of ethylene from lime storage facilities can be beneficial in retarding degreening and reducing decay

SELECTED REFERENCES:

1. Hatton, T.T. and W.F. Reeder. 1968. Quality of Persian limes after different packinghouse treatments and storage in various controlled atmospheres. Proc. Trop. Reg. Amer. Soc. Hort. Sci. 11:23-32.

2. Spalding, D.H. and W.F. Reeder. 1974. Quality of 'Tahiti' limes stored in a controlled atmosphere or under low pressure. Proc. Trop. Reg. Amer. Soc. Hort. Sci. 18:128-134.

3. Spalding, D.H. and W.F. Reeder. 1976. Low pressure (hypobaric) storage of limes. J. Amer. Soc. Hort. Sci. 101:367-370.

4. Wardowski, W.F., W. Grierson, and G.J. Edwards. 1973. Chilling injury of stored limes and grapefruit as affected by differentially permeable packaging films. HortScience 8:173-175.

COMMODITY: Mango VARIETY: (if necessary) _____

OPTIMUM TEMPERATURE: 13°C, expected range: 10° to 15°C

MODIFIED ATMOSPHERE CONSIDERATIONS:

	REDUCED O_2	INCREASED CO_2
Beneficial level:	3 - 5%	5 - 10%
Benefits:	Delayed ripening	Firmness retention
Potential for benefit:	Moderate	Slight to moderate
Injurious level:	< 2%	> 10%
Injury symptoms:	Skin discoloration, off-flavors	Off-flavors
Potential for injury:	Moderate	Moderate
Commercial use or potential:	Limited use of 5% O_2 + 5% CO_2 + 5 to 10% CO during marine transport	

REMARKS: Avoiding chilling injury is important when CA is used

SELECTED REFERENCES:

1. Hatton, T.T. and W.F. Reeder. 1967. Controlled atmosphere storage of Keitt mangoes, 1965. Proc. Carib. Reg. Amer. Soc. Hort. Sci. 10:114-119.

2. Lakshminarayana, S. and H. Subramanyan. 1970. Carbon dioxide injury and fermentative decarboxylation in mango fruit at low temperature storage. J. Food Sci. Technol. 7:148-152.

3. Spalding, D.H. and W.F. Reeder. 1974. Current status of controlled atmosphere storage of four tropical fruits. Proc. Fla. State Hort. Soc. 87:334-337.

4. Spalding, D.H. and W.F. Reeder. 1977. Low pressure (hypobaric) storage of mangos. J. Amer. Soc. Hort. Sci. 102:367-369.

COMMODITY: Nectarine VARIETY: (if necessary) _____

OPTIMUM TEMPERATURE: -0.5° to 0°C, expected range: 0° to 5°C

MODIFIED ATMOSPHERE CONSIDERATIONS:

	REDUCED O_2	INCREASED CO_2
Beneficial level:	1 - 2%	3 - 5%
Benefits:	Delayed ripening, firmness retention	A slight reduction in internal breakdown may occur in some cultivars
Potential for benefit:	Moderate	Moderate
Injurious level:	< 1%	> 10%
Injury symptoms:	Failure to ripen, skin browning, off-flavors	Flesh browning, loss of flavor
Potential for injury:	Moderate	Slight to moderate
Commercial use or potential:	Very limited use of CA + 5 to 10% CO during marine transport	

REMARKS: Internal breakdown is the limiting factor in long-term storage of many nectarine cultivars. Use of intermittent warming in combination with CA may overcome this problem in some cultivars.

SELECTED REFERENCES:

1. Anderson, R.E. 1982. Long-term storage of peaches and nectarines intermittently warmed during controlled atmosphere storage. J. Amer. Soc. Hort. Sci. 107:214-216.

2. Anderson, R.E., C.S. Parsons, and W.L. Smith, Jr. 1969. Controlled atmosphere storage of eastern-grown peaches and nectarines. USDA, Mktg. Res. Rep. 836, 19 p.

3. Mitchell, F.G., A.A. Kader, G. Crisosto, and G. Mayer. 1984. Stone fruit tolerance to high CO_2 and low O_2 atmospheres. HortScience 19:573 (abstract).

4. Olsen, K.L. and H.A. Schomer. 1975. Influence of controlled-atmosphere on the quality and condition of stored nectarines. HortScience 10:582-583.

5. Smith, W.L., Jr. and R.E. Anderson. 1975. Decay control of peaches and nectarines during and after controlled atmosphere and air storage. J. Amer. Soc. Hort. Sci. 100:84-86.

COMMODITY: Olive VARIETY: (if necessary) _____

OPTIMUM TEMPERATURE: 7°C, expected range: 5° to 10°C

MODIFIED ATMOSPHERE CONSIDERATIONS:

	REDUCED O_2	INCREASED CO_2
Beneficial level:	2 - 5%	5 - 10%
Benefits:	Delayed senescence	Firmness retention (?)
Potential for benefit:	Slight (?)	Slight (?)
Injurious level:	< 2% (?)	> 10% (?)
Injury symptoms:	Off-flavors	Increased severity of chilling injury on olives kept at < 7°C
Potential for injury:	Slight	Moderate
Commercial use or potential:	None at this time	

REMARKS: More research is needed

SELECTED REFERENCES:

1. Maxie, E.C. 1964. Experiments on cold storage and controlled atmospheres. Annu. Tech. Rep. Calif. Olive Assoc. 43:12-15.

COMMODITY: Orange VARIETY: (if necessary) _____

OPTIMUM TEMPERATURE: 7°C, expected range: 5° to 10°C

MODIFIED ATMOSPHERE CONSIDERATIONS:

	REDUCED O_2	INCREASED CO_2
Beneficial level:	5 - 10%	0 - 5%
Benefits:	Delayed senesence, firmness retention	May reduce chilling injury symptoms
Potential for benefit:	Slight	Slight
Injurious level:	< 5%	> 5%
Injury symptoms:	Off-flavors	Off-flavors
Potential for injury:	Moderate	Moderate
Commercial use or potential:	Very limited use of 5% O_2 + 5% CO_2 + 5 to 10% CO during marine transport	

REMARKS: Decay control is the limiting factor to long-term storage of oranges

SELECTED REFERENCES:

1. Biale, J.B. 1946. Critical oxygen concentrations for the carbon dioxide evolution by citrus fruits. Amer. J. Bot. 33:834.

2. Davis, P.L., B. Roe, and J.H. Bruemner. 1973. Biochemical changes in citrus fruits during controlled-atmosphere storage. J. Food Sci. 38:225-229.

3. Eaks, I.L. and W.A. Ludi. 1960. Effect of temperature, washing, and waxing on the composition of the internal atmosphere of orange fruits: Proc. Amer. Soc. Hort. Sci. 76:220-228.

4. Smoot, J.J. 1969. Decay of Florida fruit stored in controlled atmosphere and in air. Proc. 1st Int'l. Citrus Symp. 2:1283-1293.

COMMODITY: Papaya VARIETY: (if necessary) _____

OPTIMUM TEMPERATURE: 12°C, expected range: 10° to 15°C

MODIFIED ATMOSPHERE CONSIDERATIONS:

	REDUCED O_2	INCREASED CO_2
Beneficial level:	3 - 5%	5 - 10%
Benefits:	Delayed ripening	Firmness retention
Potential for benefit:	Slight to moderate	Slight to moderate
Injurious level:	< 2%	> 10%
Injury symptoms:	Off-flavors, failure to ripen	Off-flavors, may aggrevate chilling injury at < 12°C
Potential for injury:	Moderate	Moderate
Commercial use or potential:	None at this time	

REMARKS: Chilling injury should be avoided

SELECTED REFERENCES:

1. Akamine, E.K. 1969. Controlled atmosphere storage of papayas. Univ. Hawaii Ext. Misc. Publ. 64:23-24.

2. Alvarez, A.M. 1980. Improved marketability of fresh papaya by shipment in hypobaric containers. HortScience 15:517-518.

3. Hatton, T.T., Jr. and W.F. Reeder. 1969. Controlled-atmosphere storage of papayas. Proc. Trop. Reg. Amer. Soc. Hort. Sci. 13:251-256.

4. Nazeeb, M. and W.J. Broughton. 1978. Storage conditions and ripening of papaya 'Bentong' and 'Taiping'. Scientia Hort. 9:265-277.

COMMODITY: Peach, clingstone VARIETY: (if necessary) _____

OPTIMUM TEMPERATURE: -0.5° to 0°C, expected range: 0° to 5°C

MODIFIED ATMOSPHERE CONSIDERATIONS:

	REDUCED O_2	INCREASED CO_2
Beneficial level:	1 - 2%	3 - 5%
Benefits:	Delayed ripening	Firmness retention
Potential for benefit:	Good	Good
Injurious level:	< 1%	> 5%
Injury symptoms:	Off-flavors in the canned product	Internal flesh browning severity increases with CO_2%
Potential for injury:	Moderate	Moderate
Commercial use or potential:	Limited use for pre-processing storage of late-season cultivars to extend the canning season	

REMARKS: Cultivars differ greatly in their storage potential in CA or air

SELECTED REFERENCES:

1. Brecht, J.K., A.A. Kader, C.M. Heintz, and R.C. Norona. 1982. Controlled atmosphere and ethylene effects on quality of California canning apricots and clingstone peaches. J. Food Sci. 47:432-436.

2. Claypool, L.L. and L.D. Davis. 1959. Effect of cold and modified atmosphere storage on the canning quality of cling peaches. Food Technol. 13:208-212.

3. Kader, A.A. and L.A. Kitinoja. 1985. Genotypic variation in postharvest behavior of clingstone peaches. HortScience 20:579 (abstract).

COMMODITY: Peach, freestone VARIETY: (if necessary) _____

OPTIMUM TEMPERATURE: -0.5° to 0°C, expected range: 0° to 5°C

MODIFIED ATMOSPHERE CONSIDERATIONS:

	REDUCED O_2	INCREASED CO_2
Beneficial level:	1 - 2%	3 - 5%
Benefits:	Delayed ripening and softening	Slight reduction in internal breakdown of some cultivars
Potential for benefit:	Moderate	Moderate
Injurious level:	< 1%	> 10%
Injury symptoms:	Failure to ripen, skin browning, off-flavors	Flesh browning, off-flavors
Potential for injury:	Moderate	Slight to moderate
Commercial use or potential:	Very limited use of CA + 5 to 10% CO during marine transport	

REMARKS: Internal breakdown is the limiting factor to long-term storage and CA does not sufficiently overcome this problem (although one report indicates amelioration of internal breakdown by 20% CO_2 in 'J.H. Hale' peaches)

SELECTED REFERENCES:

1. Anderson, R.E., R.W. Penny, and W.L. Smith, Jr. 1977. Peach storage in a controlled atmosphere with intermittent warming: A pilot test using inexpensive flowmeters and plastic bags as CA chambers. HortScience 12:345-346.

2. Kader, A.A., M.A. El-Goorani, and N.F. Sommer. 1982. Postharvest decay, respiration, ethylene production, and quality of peaches held in controlled atmospheres with added carbon monoxide. J. Amer. Soc. Hort. Sci. 107:856-859.

3. Wade, N.L. 1981. Effects of storage atmosphere, temperature, and calcium on low temperature injury of peach fruit. Scientia Hort. 15:145-154.

See also the references listed for nectarines.

COMMODITY: Persimmon VARIETY: (if necessary) Hachiya & Fuyu

OPTIMUM TEMPERATURE: -1° to 0°C, expected range: 0° to 5°C

MODIFIED ATMOSPHERE CONSIDERATIONS:

	REDUCED O_2	INCREASED CO_2
Beneficial level:	3 - 5%	5 - 8%
Benefits:	Delayed ripening	Firmness retention, reduced chilling injury symptoms on 'Fuyu' persimmons
Potential for benefit:	Good	Good
Injurious level:	< 3%	> 10%
Injury symptoms:	Failure to ripen, off-flavors	Off-flavors
Potential for injury:	Moderate	Moderate
Commercial use or potential:	Limited use of MA packaging	

REMARKS: CO_2 at 60 - 90% for 24 hours at 17° to 20°C can be used to remove astringency of 'Hachiya' persimmons

SELECTED REFERENCES:

1. Ben-Arie, R. and S. Guelfat-Reich. 1976. Softening effects of CO_2 treatment for removal of astringency from stored persimmon fruits. J. Amer. Soc. Hort. Sci. 101:179-181.

2. Eaks, I.L. 1967. Ripening and astringency removal in persimmon fruits. Proc. Amer. Soc. Hort. Sci. 91:868-875.

3. Guelfat-Reich, S. and R. Ben-Arie. 1975. CA storage of Triumph persimmons. Suppl. Bull. Int'l Inst. Refrig. 1:119-123.

4. Matsuo, T. and S. Ito. 1977. On mechanisms of removing astringency in persimmon fruits by carbon dioxide treatment. Plant Cell Physiol. 18:17-25.

COMMODITY: Pineapple VARIETY: (if necessary) _____

OPTIMUM TEMPERATURE: 10°C, expected range: 8° to 13°C

MODIFIED ATMOSPHERE CONSIDERATIONS:

	REDUCED O_2	INCREASED CO_2
Beneficial level:	2 - 5%	5 - 10%
Benefits:	Delayed senescence, reduced respiration	Delayed degreening, slightly reduced chilling injury
Potential for benefit:	Slight to moderate	Moderate
Injurious level:	< 2%	> 10%
Injury symptoms:	Off-flavors	Off-flavors
Potential for injury:	Moderate	Moderate
Commercial use or potential:	None at this time	

REMARKS:

SELECTED REFERENCES:

1. Akamine, E.K. 1971. Controlled atmosphere storage of fresh pineapple. Univ. Hawaii Ext. Publ., 8 p.

2. Dull, G.G., R.E. Young, and J.B. Biale. 1967. Respiratory patterns in fruit of pineapple, Ananas comosus, detached at different stages of development. Physiol. Plant. 20:1059-1065.

3. Paull, R.E. and K.G. Rohrback. 1985. Symptom development of chilling injury in pineapple fruit. J. Amer. Soc. Hort. Sci. 110:100-105.

COMMODITY: Plum VARIETY: (if necessary) _____

OPTIMUM TEMPERATURE: -0.5° to 0°C, expected range: 0° to 5°C

MODIFIED ATMOSPHERE CONSIDERATIONS:

	REDUCED O_2	INCREASED CO_2
Beneficial level:	1 - 2%	0 - 5%
Benefits:	Delayed ripening	Firmness retention
Potential for benefit:	Good	Moderate to good
Injurious level:	< 1%	> 1%
Injury symptoms:	Failure to ripen, off-flavors	Flesh browning
Potential for injury:	Moderate	Moderate
Commercial use or potential:	Limited use for storage of some cultivars which are not susceptible to internal breakdown	

REMARKS: CA can be used to delay ripening at 10°C of some "slow-ripening" cultivars, and thus allow storage at this non-chilling temperature

SELECTED REFERENCES:

1. Claypool, L.L. and F.W. Allen. 1951. The influence of temperature and oxygen level on the respiration and ripening of Wickson plums. Hilgardia 21(6):129-160.

2. Couey, H.M. 1960. Effect of temperature and modified atmosphere on the storage life, ripening behavior, and dessert quality of El Dorado plums. Proc. Amer. Soc. Hort. Sci. 75:207-215.

3. Couey, H.M. 1965. Modified atmosphere storage of Nubiana plums. Proc. Amer. Soc. Hort. Sci. 86:166-168.

4. Sive, A. and D. Reznisky. 1979. Extension of the storage life of 'Red Rosa' plums by controlled atmosphere storage. Bull Int'l Inst. Refrig. 59:1148.

COMMODITY: Raspberry VARIETY: (if necessary) _____

OPTIMUM TEMPERATURE: -0.5° to 0°C, expected range: 0° to 5°C

MODIFIED ATMOSPHERE CONSIDERATIONS:

	REDUCED O_2	INCREASED CO_2
Beneficial level:	5 - 10%	15 - 20%
Benefits:	Reduced respiration rate	Reduced decay, firmness retention
Potential for benefit:	Moderate	Very good
Injurious level:	< 2%	> 25%
Injury symptoms:	Off-flavors	Off-flavors, brown discoloration
Potential for injury:	Slight to moderate	Moderate
Commercial use or potential:	Limited use within pallet covers during transport	

REMARKS: Proper temperature management is prerequisite for successful handling of raspberries

SELECTED REFERENCES:

1. Smith, W.H. 1956. The application of precooling and carbon dioxide treatment to the marketing of strawberries and raspberries. Sci. Hort. 12:147-154.

2. Winter, J.D., R.H. London, and W.H. Alderman. 1940. Use of carbon dioxide to retard the development of decay in strawberries and raspberries. Proc. Amer. Soc. Hort. Sci. 37:583-588.

COMMODITY: Strawberry VARIETY: (if necessary) _____

OPTIMUM TEMPERATURE: -0.5° to 0°C, expected range: 0° to 5°C

MODIFIED ATMOSPHERE CONSIDERATIONS:

	REDUCED O_2	INCREASED CO_2
Beneficial level:	5 - 10%	15 - 20%
Benefits:	Reduced respiration rate	Firmness retention, reduced decay
Potential for benefit:	Good	Very good
Injurious level:	< 2%	> 25%
Injury symptoms:	Off-flavors	Off-flavors, brown discoloration of berries
Potential for injury:	Slight to moderate	Moderate
Commercial use or potential:	About 60% of the strawberries shipped out of California are treated with 15 - 20% CO_2 within pallet covers following cooling to near 0°C	

REMARKS:

SELECTED REFERENCES:

1. El-Kazzaz, M.K., N.F. Sommer, and R.J. Fortlage. 1983. Effect of different atmospheres on postharvest decay and quality of fresh strawberries. Phytopathology 73:282-285.

2. Harris, C.M. and J.M. Harvey. 1973. Quality and decay of California strawberries stored in CO_2 - enriched atmospheres. Plant Dis. Reptr. 57:44-46.

3. Harvey, J.M. 1982. CO_2 atmospheres for truck shipments of strawberries, p. 359-365. In: D.G. Richardson and M. Meheriuk (eds.), Controlled atmospheres for storage and transport of perishable agricultural commodities. Timber Press, Beaverton, Oregon.

4. Sommer, N.F., F.J. Fortlage, F.G. Mitchell, and E.C. Maxie. 1973. Reduction of postharvest losses in strawberry fruit from gray mold. J. Amer. Soc. Hort. Sci. 98:285-288.