Recommended Conditions for Transportation of Fruits and Vegetables under Controlled Atmosphere (CA)

Carrier TRANSICOLD

Horticultural produce is highly perishable. Fruits and vegetables resume their metabolic activity postharvest – with respiration and transpiration leading to the consumption of substrates, and water loss accompanying ripening and senescence. In a short span of time, the produce becomes non-marketable and leads to food waste – a global problem that has worsened tremendously in the last 10 years.

Food loss can be mitigated by the efficient transportation and storage of perishables. At Carrier Transicold, we've put together a short guide[1] on the recommended conditions for refrigerated transport of your fruits and vegetables, and how EverFRESH® controlled atmosphere (CA) can benefit you and the environment by increasing postharvest transit life.

Commodity	Optimum Temperature °C	Respiration Rate ml CO_2 / kg·hr	O_2 [2]	CO_2 [2]	Initial CO_2 Injection [3]	CO_2 Injection in Transit [4]	Max Postharvest Life (Weeks)		Transit Life Extension	Potential Benefits of CA
							Air	CA		
Low Respiring										
Apple - Fuji	0.0 - 1.0	4 - 6	2%	1%	No	No	14 - 18	44 - 48	≥ 3 times	Low O_2 can retard ripening, maintain firmness, reduce scald incidence.
Apple - Gala	0.0 - 1.0	6.5 - 8	2%	2%	No	Possibly	8 - 12	20 - 24	≥ 2 times	Retard ripening, maintain firmness, prevent scald incidence.
Apple - Golden Delicious	0.0 - 1.0	3 - 6	2%	2 - 3%	No	Possibly	12 - 16	32 - 40	≥ 2.5 times	Retard ripening, maintain firmness, acidity, and skin color, reduce core flush.
Apple - Granny Smith	0.0 - 1.0	2 - 4	2%	1%	No	No	12 - 16	40 - 44	≥ 2.5 times	Low O_2 can retard ripening, maintain firmness and acidity, reduce scald incidence and core flush.
Apple - McIntosh	2.0 - 3.0	2 - 8	2%	2%	No	Possibly	8 - 12	20 - 28	≥ 2.3 times	Retard ripening, maintain firmness, and acidity.
Apple - Red Delicious	0.0	2 - 5	2%	2%	No	Possibly	12 - 16	44 - 48	≥ 3 times	Retard ripening, maintain firmness and acidity, reduce scald incidence.
Apricot	-0.5 to 0.0	2 - 4	2 - 3%	2 - 3%	No	Possibly	1 - 2	2 - 4	≥ 2 times	Delay ripening and softening, maintain color.
Bell Pepper	7.0 - 10.0	3 - 8	2 - 5%	2 - 5%	No	Possibly	2 - 4	3 - 5	≥ 1.2 times	May retard ripening, maintain green color, and delay decay.
Blueberry	-0.5 to 0.5	3 - 4	2 - 5%	12 - 19%	Yes	Possibly	1 - 3	8 - 10	≥ 3 times	Maintain firmness and color, reduce water loss and dehydration. Elevated CO_2 can delay decay (botrytis mold and others).
Cabbage	0.0	2 - 3	3 - 5%	3 - 7%	Possibly	Possibly	3 - 6	5 - 8	≥ 1.3 times	Reduce decay, sprouting, and loss of green color.
Cactus (Prickly) Pear	5.0	3 - 6	2%	2 - 5%	Possibly	Possibly	2 - 5	4 - 7	≥ 1.4 times	Delay ripening , decay, and maintain visual quality.
Cantaloupe	2.0 to 3.0	2 - 5	3 - 5%	10 - 15%	Yes	Yes	2 - 3	4 - 5	≥ 1.5 times	Retard ripening. Elevated CO2 can reduce decay, and sugar loss.
Celery	0.0	3 - 4	2 - 4%	3 - 5%	Possibly	Possibly	4 - 7	5 - 9	≥ 1.2 times	Delay decay, and discoloration of damaged tissue.
Cherry, Sweet	-0.5 to 1.0	3 - 5	3 - 8%	10 - 14%	Yes	Yes	3 - 4	4 - 6	≥ 1.3 times	Maintain firmness, freshness, juiciness, and turgidity. Elevated CO_2 can delay decay.
Fig	-0.5 to 0.0	2 - 4	5 - 10%	12 - 17%	Yes	Yes	1 - 2	2 - 4	2 times	Elevated CO_2 can maintain firmness and reduce decay. Only slight benefit from low O_2.
Garlic	-0.5 to 0.0	2 - 6	2%	5 - 10%	Yes	Yes	16 - 24	16 - 32	≥ 1.1 times	Retard decay. Elevated CO_2 can reduce sprouting and root growth.
Grape	-0.5 to 0.0	1 - 2	5 - 10%	10 - 15%	Yes	Yes	4 - 16 (SO_2)	4 - 18	≥ 1.1 times	Low O_2 can delay senescence. Elevated CO_2 can reduce decay. CA can substitute for the use of SO_2.
Grapefruit	10.0 - 14.0	3 - 7	3 - 10%	5 - 10%	Yes	Yes	4 - 6	6 - 8	≥ 1.3 times	Maintain firmness, reduce stem-end breakdown and chilling injury symptoms. Fungistatic protection by CO_2 can only be attained if CO_2 is above 10 to 15% (injurious to grapefruits).
Kiwifruit	0.0 - 1.0	1.5 - 2	2 - 3%	3 - 5%	Possibly	Possibly	2 - 3	3 - 5	≥ 1.5 times	Delay ripening and maintain firmness.
Lettuce Crisphead	0.0 - 1.0	3 - 8	2 - 3%	≤ 2%	No	No	2 - 3	3 - 5	≥ 1.5 times	Delay senescence and reduce disorders such as pink rib. Elevated CO2 > 2% can induce brown stain on the mid ribs of leaves.
Lettuce Romaine	0.0 - 1.0	3 - 8	2 - 3%	≤ 2 - 3%	No	No	2 - 3	3 - 5	≥ 1.5 times	Delay senescence and reduce disorders such as pink rib. Elevated CO2 > 2-3% can induce brown stain on the mid ribs of leaves.
Lime	9.0 - 12.0	3 - 6	5 - 10%	4 - 10%	Possibly	Possibly	3 - 6	4 - 8	≥ 1.3 times	May delay senescence and loss of green color. Fungistatic protection by CO_2 can only be attained if CO_2 is above 10 to 15% (injurious to limes).
Lychee	2.0 - 6.0	3 - 8	3 - 5%	3 - 5%	Possibly	Possibly	2 - 5	4 - 6	≥ 1.2 times	Reduce ripening and skin browning, delay decay and loss of ascorbic acid and acidity. CA can substitute for the use of SO_2.
Mandarin - Tangerine	5.0 - 8.0	2 - 5	5 - 8%	2 - 5%	Possibly	Possibly	3 - 5	4 - 7	≥ 1.3 times	Delay senescence and color changes, maintain freshness. Fungistatic protection by CO_2 can only be attained if CO_2 is above 10 to 15% (injurious to mandarins).
Mangosteen	12.0 - 13.0	4 - 6	2 - 5%	5 - 10%	Yes	Yes	2 - 4	3 - 5	≥ 1.2 times	May retard ripening, color changes and may help maintain firmness and internal quality.
Nectarine	-0.5 to 0.0	2 - 3	2%	3 - 5%	Possibly	Possibly	3 - 4	4 - 6	≥ 1.3 times	Delay ripening and maintain firmness, reduce internal breakdown.
Onion	0.0	3 - 4	2 - 3%	4 -10%	Yes	Yes	5 - 7	6 - 10	≥ 1.2 times	Elevated CO_2 may reduce sprouting and root growth (high valued sweet onions like Vidalia, Maui, Walla Walla). Low O_2 has little benefit.
Onion, Green	0.0	5 - 16	2 - 4%	1 - 5%	Yes	Yes	3 - 4	5 -8	≥ 1.6 times	Reduce decay, sprouting, and root growth. Maintain firmness and freshness.
Orange	2.0 - 8.0	2 - 4	5 - 10%	1 - 5%	Possibly	Possibly	4 - 10	6 - 12	≥ 1.2 times	May delay senescence, maintain firmness, and reduce chilling injury symptoms. Fungistatic protection by CO_2 can only be attained if CO_2 is above 10 to 15%. (injurious to oranges).
Peach	-0.5 to 0.0	2 - 3	2%	3 - 5%	Possibly	Possibly	2 - 4	4 -6	≥ 1.5 times	Delay ripening and softening. Maintain firmness, and prevent internal breakdown. Some varieties of peaches can be shipped in 6% O_2 and 17% CO_2 at 0°C.
Pear - Asian	0.0 - 1.0	2 - 3	2 - 5%	≤ 2%	No	No	16 - 24	20 - 28	≥ 1.1 times	Low O_2 can maintain firmness, peel color, and allow greater capacity for ripening at markets.
Pear - Bartlett	-0.5 to 0.0	2 - 3	2 - 3%	1 - 2%	No	No	8 - 12	12 - 24	≥ 1.5 times	Delay ripening and softening. Reduce incidence of brown core. Maintain firmness and allow greater capacity for ripening at markets.
Pear - Bosc	-0.5 to 0.0	2 - 3	2 - 2.5%	1%	No	No	8 - 12	12 - 28	≥ 1.5 times	Low O_2 can delay ripening and softening. Reduce incidence of brown core. Maintain firmness and allow greater capacity for ripening at markets.
Pear - Comice	-0.5 to 0.0	2 - 3	3%	1%	No	No	8 - 12	12 - 28	≥ 1.5 times	Low O_2 can delay ripening and softening. Reduce incidence of brown core. Maintain firmness and allow greater capacity for ripening at markets.
Pear - Conference	-0.5 to 0.0	2 - 3	2.5 - 3%	1%	No	No	8 - 12	12 - 28	≥ 1.5 times	Low O_2 can delay ripening and softening. Reduce incidence of brown core. Maintain firmness and allow greater capacity for ripening at markets.
Pear - D'Anjou	-0.5 to 0.0	1 - 3	2 - 2.5%	1%	No	No	12 - 24	16 - 32	≥ 1.3 times	Low O_2 can delay ripening and softening. Maintain green color and acidity. Reduce incidence of brown core and scald incidence. Maintain firmness and allow greater capacity for ripening at markets.
Pear - Packham's	-0.5 to 0.0	2 - 3	2 - 3%	1 - 3%	No	No	8 - 12	12 - 28	≥ 1.5 times	Delay ripening and softening, green color, acidity. Reduce incidence of brown core and scald incidence. Maintain firmness and allow greater capacity for ripening at markets.
Persimmon	0.0	2 - 4	3 - 5%	5 - 8%	Possibly	Possibly	6 - 10	8 - 14	≥ 1.3 times	Delay ripening, maintain firmness, and reduce chilling injury symptoms.
Pineapple	7.0 - 8.0	2 - 4	2 - 5%	≤ 2%	Possibly	Possibly	2 - 4	4 - 6	≥ 1.5 times	May delay senescence and de-greening of crown. May reduce flesh translucency (water-soaked flesh). Fungistatic protection by CO_2 against crown mold would only be attained if CO_2 is above 10 to 15%. (injurious to pineapples).
Plum	-0.5 to 0.0	1 - 2	2%	2 - 5%	Possibly	Possibly	3 - 6	6 - 8	≥ 1.3 times	Low O_2 can delay ripening. Elevated CO_2 can maintain firmness, ground color, and reduce internal breakdown.
Pomegranate	2.0 - 6.0	2 - 4	2 - 5%	6 - 15%	Yes	Yes	2 - 6	6 - 10	≥ 1.6 times	Reduce chilling injury symptoms, reduce scald incidence. High CO_2 can retard decay.
Low to Moderate Respiring										
Bean, Snap	5.0 - 7.0	17 - 23	2 - 3%	4 - 7%	Possibly	Possibly	1 - 2	2 - 4	2 times	Reduce color loss and discoloration due to physical injury.
Blackberry	-0.5 to 0.5	10 - 11	5 - 8%	10 - 18%	Yes	Yes	< 1	1 - 2	≥ 1.1 times	Delay softening, reduce water loss and dehydration. Elevated CO_2 can delay decay (botrytis mold and others).
Broccoli	0.0	10 - 11	2 - 3%	6 - 7%	Possibly	Possibly	1 - 2	2 - 5	≥ 2 times	Delay yellowing of flower buds, reduce decay, help preserve vitamins C and A.
Brussels Sprouts	0.0	5 - 15	2 - 5%	5 - 7%	Possibly	Possibly	3 - 5	4 - 6	≥ 1.3 times	Reduce yellowing and retard decay.
Cauliflower	0.0	8 - 9	2 - 3%	3 - 4%	Possibly	Possibly	2 - 3	3 - 5	≥ 1.5 times	Low O_2 can maintain white curd and green leaves, and reduce weight loss and curd spotting. No tangible benefit from high CO_2.
Honeydew	7.0 - 10.0	7 - 9	3 - 5%	5 - 10%	Yes	Yes	3 - 4	4 - 6	≥ 1.3 times	Delay ripening and decay.
Lemon	10.0 - 13.0	5 - 8	6 - 8%	4 - 8%	Yes	Yes	4 - 10	6 - 12	≥ 1.2 times	Delay loss of green color and maintain juiciness. Fungistatic protection by CO_2 can only be attained if CO_2 is above 10 to 15% (injurious to lemons).
Longan	4.0 - 7.0	3 - 12	2 - 5%	5 - 15%	Yes	Yes	2 - 3	3 - 4	≥ 1.3 times	Delay skin browning and decay, maintain firmness. CA could substitute for the use of SO_2.
Olive	5.0 - 10.0	5 - 16	2 - 3%	1%	No	No	4 - 6	6 - 8	≥ 1.3 times	Delay senescence and retard softening, maintain firmness.
Papaya	7.0 - 13.0	3 - 12	3 - 5 %	5 - 8%	Possibly	Possibly	1 - 3	2 - 5	≥ 1.5 times	Delay ripening, decay, and softening. Maintain firmness.
Raspberry	-0.5 to 0.0	11 - 13	5 - 8%	10 - 18%	Yes	Yes	< 1	1 - 2	≥ 1.1 times	Maintain color, firmness, and integrity. Elevated CO_2 can delay decay.
Sapote, Black, Mamey	12.0 - 13.0	5 - 10	5%	5 - 10%	Yes	Yes	2 - 4	4 - 5	≥ 1.2 times	Elevated CO_2 may delay ripening and deterioration. Low O_2 has little benefit.
Starfruit (Carambola)	7.0 - 10.0	6 - 15	2 - 4%	5 - 8%	Possibly	Possibly	2 - 3	3 - 5	≥ 1.5 times	May retard ripening and deterioration.
Strawberry	0.0	6 - 10	5 - 10%	15 - 20%	Yes	Yes	1 - 2	2 - 4	2 times	Elevated CO_2 can help maintain firmness and retard decay. Low O_2 has little benefit.
Tomato	7.0 - 14.0	7 - 8	3 - 5%	2 - 3%	No	No	1 - 4	3 - 5	≥ 1.2 times	Delay ripening, color changes, and decay on surface and stem scar.
Moderate to High Respiring										
Asparagus, Green	0.0 - 2.0	14 - 50	10 - 15%	10 - 15%	No	No	1 - 2	2 - 4	2 times	Elevated CO_2 can maintain tenderness and color, and retard development of soft rot. No tangible benefit from low O_2.
Avocado	5.0 - 8.0	10 - 25	2 - 5%	4 - 10%	No	No	2 - 4	4 - 6	≥ 1.5 times	Delay ripening, softening and decay, reduce symptoms of chilling injury.
Banana	13.3 - 14.5	10 - 35	3 - 5%	5 - 6%	No	No	2 - 4	4 - 6	≥ 1.5 times	Delay ripening, retard decay, maintain firmness, and reduce peel split.
Cherimoya	12.0 - 13.0	35 - 130	3 - 5%	5 - 10%	No	No	2 - 4	4 - 6	≥ 1.5 times	Retard ripening, maintain firmness, delay discoloration.
Corn, Sweet	0.0	30 - 50	2 - 10%	5 - 15%	No	No	1 - 2	3 - 4	2 times	Reduce decay. Elevated CO_2 can reduce loss of sugar from kernels and loss of chlorophyll from husks.
Cucumber	10.0 - 12.0	12 - 16	3 - 5%	3 - 7%	Possibly	Possibly	1 - 2	3 - 4	≥ 2 times	Delay senescence and chlorophyll loss, retard yellowing.
Dragon Fruit	8.0 - 10.0	15 - 25	3 - 4%	5 - 7%	Possibly	Possibly	2 - 4	3 - 6	≥ 1.5 times	May help delay ripening and peel discoloration.
Durian	12.0 - 14.0	6 - 60	4 - 5%	5 - 15%	No	No	1 - 5	4 - 7	≥ 1.4 times	Delay ripening and senescence, reduce production of sulfurous odor. Elevated CO_2 can delay decay.
Guava	5.0 - 10.0	4 - 30	5 - 8%	3 - 5%	Possibly	Possibly	2 - 3	3 - 4	≥ 1.3 times	Delay ripening and softening, and reduce chilling injury.
Mango	10.0 - 13.0	12 - 22	3 - 5%	5 - 10%	Possibly	Possibly	2 - 3	3 - 5	≥ 1.5 times	Delay ripening and decay. Maintain firmness. Anthracnosis from the field can only be prevented if CO_2 is above 10-15% (injurious to mango).
Mushroom	0.0	14 - 22	3 - 20%	5 - 15%	Yes	Yes	1 - 2	3 - 5	≥ 2.5 times	Reduce growth of micro-organisms, reduce cap opening and browning of stipe and gills.
Okra	7.0 - 10.0	27 - 47	5 - 10%	4 - 10%	No	No	1 - 2	2 - 3	≥ 1.5 times	Elevated CO_2 may delay decay, and maintain tenderness, high mucilage, and green color. Low O_2 has limited benefit.
Passion Fruit	7.0 - 10.0	15 - 40	4 - 5%	10 - 15%	Possibly	Possibly	3 - 4	4 - 6	≥ 1.3 times	May delay ripening and decay, and maintain firmness. May help maintain acidity and Vit C content.
Pea - Snow, Sugar	0.0	15 - 23	2 - 3%	3 - 6%	Possibly	Possibly	1 - 2	2 - 3	≥ 1.5 times	Maintain sugars and green color. Retard development of soft rot.
Rambutan	10.0 - 12.0	8 - 22	3 - 5%	7 - 12%	Possibly	Possibly	1 - 2	2 - 4	2 times	Retard senescence, slow down loss of red color. Maintain firmness, and reduce incidence of chilling injury. High CO_2 can delay decay.
Sweetsop, Sugar Apple	12.0 - 15.0	25 - 65	3 - 5%	5 - 10%	No	No	2 - 3	4 - 5	≥ 1.6 times	May reduce ripening and delay deterioration.

[1] The potential benefits and recommended conditions indicated are dependent on various parameters including the type of product, variety, maturity, age, growing region, season, following best postharvest handling practices, adequate and complete pre-cooling protocols, proper temperature management and control, complying with the cold chain, using proper CA conditions, and trip length.

[2] Recommended CA setpoints are based on optimum conditions applied to the transportation of fresh cargo in a reefer.

[3] Initial CO_2 injection is required if recommended levels of CO_2 are high and / or if respiration rate of commodity is low.

[4] The injection of CO_2 option in transit offers more precise control of optimum CO_2 levels during the trip.