Kader, A.A. 1994. Modified and controlled atmosphere storage of tropical fruits, p. 239-249, In: Champ, B.R. et al. (editors). Postharvest handling of tropical fruits: proceedings of an international conference held at Chiang Mai, Thailand, 19-23 July 1993. ACIAR Proceedings No. 50, ACIAR, Canberra, Australia.

Modified and Controlled Atmosphere Storage of Tropical Fruits

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Abstract

Modified and controlled atmospheres (MA/CA) can be used to supplement the maintenance of optimum temperature and relative humidity for preserving quality and reducing postharvest losses of tropical fruits during transport and storage. MA/CA reduce respiration rate, ethylene production and action, compositional changes associated with ripening, and incidence of some physiological disorders. Using MA/CA to delay fruit ripening at temperatures above the chilling range, exposure of tropical fruits to chilling injury-inducing temperatures can be avoided. Carbon dioxide at 15–20% is an effective fungistat that can be used to retard decay incidence on fruits which tolerate such CO_2 concentrations. MA/CA conditions including up to 60% CO_2 and/or less than 1% O_2 are insecticidal against some insects of quarantine importance on certain fruits. Such treatments alone or in combination with cold or heat treatments will likely become part of postharvest integrated pest management programs for tropical fruits. Exclusion and removal of ethylene from transport and storage environments contribute to delaying fruit ripening and reducing growth of decay-causing pathogens. Recent advances in MA/CA technology are facilitating expanded use on intact and lightly processed fruits and this trend is expected to continue in the future.

MA/CA can supplement proper temperature and relative humidity management in maintaining quality and reducing losses of tropical fruits. The beneficial effects of MA/CA include reduction of respiration rate, inhibition of ethylene production and action, retardation of ripening, and maintenance of nutritional quality. The delay of ripening by MA/CA can facilitate transporting and storing tropical fruits at temperatures above those that cause chilling injury.

Short-term exposure of tropical fruits to O_2 levels below 1% and/or CO_2 levels above 12% can reduce incidence and severity of physiological disorders (such as chilling injury), pathogens, and insects. The tolerance limits of tropical fruits to insecticidal CAs depend upon storage temperature, O_2 and CO_2 concentrations, fruit resistance to gas diffusion, ethanol accumulation rate, and soluble solids content. Some tropical fruits tolerate insecticidal CAs for 2–5 days at 20°C though further research is needed to find out whether these durations are adequate for killing insects of quarantine importance such as tropical fruit flies.

Effective control of anthracnose and other pathogens is essential to successful use of MA/CA during transport and storage of tropical fruits. Fungistatic levels of CO_2 (15% or higher) should be tested for their efficacy in controlling postharvest diseases without detrimental effects on the quality of tropical fruits. The cost/benefit (in terms of reducing decay incidence and severity) ratio of removing ethylene from the environment surrounding tropical fruits during postharvest handling merits investigation.

Research on responses of tropical fruits to MA/CA has largely been limited to avocado, banana, mango, papaya, and pineapple. The current CA recommendations for these commodities and for five others with which limited studies have been done (cherimoya, sweetsop, durian, lychee, and rambutan) are summarised in the following tables. It should be noted that specific CA combination depends on cultivar, temperature, and duration of storage. These recommendations are for transport and/or storage beyond 2 weeks. Exposure to lower O_2 and/or higher CO_2 concentrations for shorter durations may be used for control of some physiological disorders, pathogens, and/or insects. In general, postharvest life (based on maintenance of textural and flavour quality) of these fruits is extended by 50–100% when kept in CA relative to air at optimum temperature and relative humidity.

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Avocado (*Persae americana* Mill.)

Optimum temperature: 10°C, expected range: 5–13°C

Modified atmosphere considerations:

	Reduced O_2	Increased CO_2
Beneficial level:	2–5 %	3–10%
Benefits:	Delayed ripening, reduced rates of CO_2 and C_2H_4 production	Delayed softening, reduced chilling injury symptoms
Potential for benefits:	Good	Good
Injurious level:	< 1%	> 15%
Injury symptoms:	Off-flavour, internal flesh browning	Skin browning, off-flavours
Potential for injury:	Moderate	Moderate

Commercial use or potential: Use during long-distance transport is expanding.

Remarks: CO at 5–10% added to CA may be useful in reducing decay problems. Exposure to 25–30% CO_2 for 2–3 days can delay decay incidence during subsequent storage in air or CA. Exclusion and/or removal of ethylene (<1 ppm) from air or CA storage are recommended.

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Banana (*Musa* spp.)

Optimum temperature: 14°C, expected range: 12–16°C

Modified atmosphere considerations:

	Reduced O_2	Increased CO_2
Beneficial level:	2–5 %	2–5%
Benefits:	Delayed ripening	Delayed ripening
Potential for benefits:	Very good	Very good
Injurious level:	< 1%	> 7%
Injury symptoms:	Dull yellow or brown skin discoloration, failure to ripen, off-flavours	Green fruit softening undesirable texture & flavour
Potential for injury:	High	Moderate to high

Commercial use or potential: Use during long-distance transport is expanding. Modified atmospheres (1–5% O_2 and 4–6% CO_2) and/or ethylene-absorbers are also used commercially during transport and distribution.

Remarks: Cooking bananas and plantains have similar CA requirements

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Mango (*Mangifera indica* L.)

Optimum temperature: 13°C, expected range: 10–15°C

Modified atmosphere considerations:

	Reduced O_2	Increased CO_2
Beneficial level:	3–5% (5–7% SE Asia-grown varieties)	5–10%
Benefits:	Delayed ripening	Firmness retention
Potential for benefits:	Moderate	Slight to moderate
Injurious level:	< 2% (< 5%)	> 10%
Injury symptoms:	Skin discoloration, off-flavours greyish flesh colour	Off-flavours, softening,
Potential for injury:	Moderate	Moderate

Commercial use or potential: Limited use of 5% O_2 + 5% CO_2 + 5–10% CO during marine transport.

Remarks: Avoiding chilling injury is important when CA is used. Use of heat treatments to reduce anthracnose is highly recommended.

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Papaya (*Carcia papaya* L.)

Optimum temperature: 12°C, expected range: 10–15°C

Modified atmosphere considerations:

	Reduced O_2	Increased CO_2
Beneficial level:	2–5%	5–8%
Benefits:	Delayed ripening (degreening and softening)	Firmness retention
Potential for benefits:	Slight to moderate	Slight to moderate
Injurious level:	< 2%	> 8%
Injury symptoms:	Off-flavours, failure to ripen	Off-flavours, may aggravate chilling injury at < 12°C
Potential for injury:	Moderate	Moderate

Commercial use or potential: None at this time; waxing may be used to modify internal O_2 and CO_2 concentrations.

Remarks: Chilling injury should be avoided when CA is used. Prestorage treatments to minimise decay during storage are essential to successful storage.

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Pineapple (*Ananas comosus* (L.) Merril.)

Optimum temperature: 10°C, expected range: 8–13°C

Modified atmosphere considerations:

	Reduced O_2	Increased CO_2
Beneficial level:	2–5%	5–10%
Benefits:	Delayed senescence, reduced respiration	Delayed degreening, reduced chilling injury
Potential for benefits:	Slight to moderate	Moderate
Injurious level:	< 2%	> 10%
Injury symptoms:	Off-flavours	Off-flavours
Potential for injury:	Moderate	Moderate

Commercial use or potential: Very limited

Remarks: Waxing may be used to modify O_2 and CO_2 concentration within the fruit enough to reduce incidence and severity of endogenous brown spot.

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Cherimoya (*Annona cherimola* Mill.)

Optimum temperature: 10°C, expected range: 8–15°C

Modified atmosphere considerations:

	Reduced O_2	Increased CO_2
Beneficial level:	5%	5–10%
Benefits:	Lower respiration and ethylene production rates, retarded ripening, firmness retention	Delayed ripening
Potential for benefits:	Good	Moderate
Injurious level:	< 1%	?
Injury symptoms:	Off-flavours	?
Potential for injury:	High	?
Commercial use or potential:	Cherimoyas can be kept for up to 6 weeks at 10 °C in 5% O_2, then ripened with good flavour at 20°C.	

Remarks: Ethylene removal can be helpful in retarding ripening.

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Sweetsop (custard apple) (*Annona squamosa* L.)

Optimum temperature: 15°C, expected range: 12–20°C

Modified atmosphere considerations:

	Reduced O_2	Increased CO_2
Beneficial level:	3–5%	5–10%
Benefits:	Reduced ethylene production and respiration, delayed ripening	Delayed ripening
Potential for benefits:	Good	Moderate
Injurious level:	< 1%	15% and higher
Injury symptoms:	Failure to ripen	Flat taste and uneven ripening
Potential for injury:	High	Moderate

Commercial use or potential: None at this time (July 1993)

Remarks: Ethylene removal can be helpful in retarding ripening.

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Durian (*Durio zibethinus* J. Murr.)

Optimum temperature: 15°, expected range: 12–20°C

Modified atmosphere considerations:

	Reduced O_2	Increased CO_2
Beneficial level:	3–5%	5–20%
Benefits:	Lowered CO_2 and C_2H_4 production rates, retarded ripening	Retarded ripening if combined with 10% or lower O_2
Potential for benefits:	Good	Moderate
Injurious level:	< 2%	> 20%
Injury symptoms:	Failure to ripen, grey discolouration of pulp	?
Potential for injury:	High	?

Commercial use or potential: None at this time (July 1993)

Remarks: Modified atmosphere packaging and waxing can reduce CO_2 and C_2H_4 production rates and sulphurous odour characteristic of ripe durian.

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Lychee (Litchi) (*Litchi chinensis* Sonn.)

Optimum temperature: 7°, expected range: 5–12°C

Modified atmosphere considerations:

	Reduced O_2	Increased CO_2
Beneficial level:	5%	3–5%
Benefits:	Reduced skin browning and polyphenoloxidase activity	Slower rates of losses of ascorbic acid, acidity, and soluble solids
Potential for benefits:	Good	Moderate
Injurious level:	?	?
Injury symptoms:	?	?
Potential for injury:	?	?

Commercial use or potential: Modified atmosphere packaging is used to a limited extent.

Remarks: Maintenance of high relative humidity is essential for reduction of water loss and browning.

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Rambutan (*Nephelium lappaceum* L.)

Optimum temperature: 10°, expected range: 8–15°C

Modified atmosphere considerations:

	Reduced O_2	Increased CO_2
Beneficial level:	3–5%	7–12%
Benefits:	Retardation of senescence, lower respiration rate	Retarded red colour loss, extended postharvest life to about one month if water loss is minimised
Potential for benefits:	Slight	Moderate
Injurious level:	< 1%	> 20%
Injury symptoms:	Increased decay incidence	?
Potential for injury:	High	?

Commercial use or potential: Modified atmosphere packaging has potential for maintaining quality.

Remarks: Maintenance of high relative humidity is essential to minimising water loss and darkening of the skin.

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