

Rapid Reduction in Aroma Volatiles of 'Pacific Rose' Apples in Controlled Atmospheres

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Abstract

Aroma volatiles make an important contribution to the flavour and eating quality of apples (*Malus ×domestica*). While controlled atmosphere (CA) storage reduces the rate of decline of fruit quality attributes such as texture and colour, it also reduces flavour after prolonged storage. When 'Pacific Rose' apples (a new cultivar recently developed in New Zealand) were placed in CA (1.5% O₂ + 1.3% CO₂) at 0.5°C, significant decreases in aroma volatile concentrations occurred within 4 weeks compared to fruit in regular air (RA). The magnitude of aroma volatile suppression by CA increased with storage time and with subsequent shelf life at 20°C and was not reversible on transfer to air. After 4 weeks in CA, concentration of butyl acetate, a key aroma volatile compound, was only 34% that in RA; after 26 weeks there was no butyl acetate in CA fruit whilst high concentrations (738 mM L⁻¹) remained in RA fruit. Despite the large reduction in aroma volatile concentrations an untrained taste panel found only a slight reduction in flavour intensity and no undesirable flavours in CA fruit. Conversely, some panellists identified an off-flavour in RA stored fruit that increased as storage and shelf life time increased. Significant differences in aroma volatile concentrations between RA and CA stored fruit may have commercial implications for consistency of flavour and quality between lines of 'Pacific Rose' apples.

INTRODUCTION

Controlled atmosphere (CA) storage allows apple industries to store fruit for up to 12 months. Such fruit remain relatively firm with good external appearance but consumers are recognising that it is not truly fresh. Some cultivars sustain major reductions of aroma volatiles on removal to air after 3-6 months in CA storage (Streif and Bangerth, 1988; Mattheis et al., 1991; Yahia, 1994). Measurable reductions have been noted after 10-12 weeks. The extent and speed of recovery of aroma volatile production after CA varies with both cultivar and storage time with total suppression and lack of recovery reported for 'McIntosh' apples after 320 days in CA (Lidster et al., 1983).

'Pacific Rose' is a new apple cultivar from a 'Gala' × 'Splendour' cross, that is becoming popular internationally. It has good storage potential, maintaining firmness throughout extended periods in air at 0°C (J.W. Johnston and E.W. Hewett, unpublished results). The objective of this work was to compare aroma volatile production from this cultivar after storing in air and CA for up to 26 weeks.

MATERIALS AND METHODS

'Pacific Rose' apples (count size 88, average weight 210 g) were harvested at commercial export maturity, packed into 18.5 kg cartons and placed into a commercial coolstore in air or in CA (1.5% O₂ + 1.3% CO₂) at 0.5°C. After 4, 10, 18 and 26 weeks fruit was removed to 20°C shelf life conditions prior to quality determination and extraction of volatile compounds from expressed apple juice using diethylether: *n*-pentane (2:1 v/v) as a solvent (Dixon and Hewett, 2000). Analysis of aroma volatiles was undertaken by injecting 1 µl of concentrated juice into a Hewlett Packard gas

chromatograph Model 5085 (Dixon and Hewett, 2000).

An untrained panel of 50 people, (1) used a Triangle Difference procedure to determine if a difference existed between three samples provided when two of them were from the same treatment; (2) were asked to identify the aroma detected, based on published apple aroma descriptors; and (3) indicated their preferred sample from the three provided.

RESULTS AND DISCUSSION

Total volatile concentration, comprising 28 measured components (8 alcohols, 4 aldehydes and 16 esters) and measured 12 h after removal from 0.5°C to 20°C, remained constant in air stored fruit throughout 26 weeks storage. In contrast total volatiles in CA stored fruit decreased from about 27 mmol L⁻¹ initially to 3.5 mmol L⁻¹ after 26 weeks, decreasing by 20, 40, 50 and 86% after 4, 10, 18 and 26 weeks respectively (Fig. 1).

One day after removal from 0°C to 20°C total volatiles from RA fruit declined as time in storage increased but remained constant or increased through 10 days shelf life (Fig. 2). In contrast total volatiles declined dramatically in CA fruit, both with time at 0.5°C and through 10 days at 20°C. Recovery of volatile production occurred after RA storage, especially after 18 and 26 weeks, but not in CA fruit.

Alcohol

Alcohols showed the same overall pattern as total volatiles for both RA and CA fruit. Because alcohols are important precursors of esters in apples (Dimick and Hoskin, 1983), any reduction in concentration will affect aroma volatile concentrations.

1. Ethanol. Ethanol contributed variably (0-80%) to total alcohol concentration in fruit, having similar patterns of change during shelf life after removal from both RA and CA storage (data not shown). Concentration declined as time in RA increased.

2. Butanol. Butanol concentrations varied from 3 to 60% of total alcohol concentration in fruit from both RA and CA treatments. Presence of this alcohol is critical because it is a precursor of butyl esters so important in aroma development (Dimick and Hoskin, 1983).

Butanol in RA. Butanol concentrations remained relatively constant during shelf life following removal from RA after 4 and 10 weeks, but increased 2 to 3 fold on removal after 18 and 26 weeks (Fig. 3).

Butanol in CA. Butanol concentrations in CA fruit were much reduced compared with RA fruit at all removal times from coolstore and during subsequent shelf life. After 18 and 26 weeks concentrations were negligible (Fig. 3). This progressively increasing reduction in butanol concentration from as early as 4 weeks in CA stored fruit, together with the inability to recover when returned to air, suggests that expected taste and flavour might be reduced to less than acceptable levels.

Acetate

Butyl acetate concentrations from RA fruit did not change consistently at 0.5°C remaining between 0.6 and 1.2 mmol L⁻¹; during shelf life at 20°C there was a slight initial decline before concentrations increased through 10 days with the largest increase occurring after 26 weeks (data not shown). In CA fruit at 0.5°C butyl acetate decreased more than 60% after 4 weeks and was only just detectable after 26 weeks, declining further to very low concentrations at 20°C after all removals.

Esters

Total esters in RA fruit decreased slightly with time at 0.5°C, remaining constant or increasing after transfer to 20°C especially after 18 and 26 weeks. CA fruit showed a substantial and progressive decline of total esters at 0.5°C; this continued on transfer to 20°C with no recovery on transfer to air even after only 4 weeks in CA (Fig. 4).

Sensory Evaluation

An untrained panel of 50 people was used in an attempt to relate objective GLC

measurements of aroma volatiles to sensory and preference scores for fruit from RA and CA storage. There was no difference in preference between treatments for fruit evaluated after 3 days at 20°C following 10 weeks at 0.5°C, but after 10 days CA fruit was preferred (Table 1). After 26 weeks CA fruit was preferred.

CONCLUSIONS

Significant and irreversible reductions of some compounds that contribute to apple aroma and flavour occurred within 4 weeks in CA storage. It is possible that such a rapid and non-reversible effect of CA on volatile production could occur even sooner than 4 weeks. Although similar decreases have been shown to occur within 6-10 weeks of exposure to CA (Lidster et al., 1983; Patterson et al., 1974) most reports determine the effect after 3-9 months storage.

Alcohols, aldehydes and esters all decrease with time in CA relative to RA storage. The inability of fruit to produce these compounds on return to air at ambient temperatures after CA storage, indicates that their biosynthesis is impaired by CA. Thus the potential exists for consumer resistance to develop when fruit that appears to be 'fresh' (firm and juicy) on removal from CA, is found to have a substantial flavour reduction on consumption.

An untrained taste panel preferred CA fruit to RA fruit after 26 weeks storage. This apparent disparity between objective and subjective assessments of quality demonstrates the difficulty in determining specific quantitative quality attributes, such as concentrations of total or particular esters, in isolation from the overall perception of quality determined when tasting. It is almost impossible for untrained panellists to isolate the influence of firmness and juiciness from aroma and flavour when making their judgements. This difficulty is a common problem when comparing subjective and objective methods of quality assessment (Mattheis and Fellman, 1999).

That such dramatic and irreversible reductions in a range of aroma compounds and their precursors occur following such short periods of exposure to CA suggests that efforts should be intensified to develop practical techniques to alleviate or reverse the undesirable changes. Dynamic atmosphere storage (Mattheis et al., 1998) or hypoxic treatments (Dixon and Hewett, 2000) undoubtedly have potential to reduce loss of flavour volatiles induced by CA. In addition plant breeders should expose advanced selection lines of fruit to CA storage prior to final release to ensure that new releases do not have unacceptable flavour loss when maintained in CA storage.

ACKNOWLEDGEMENTS

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Tables

Table 1. Influence of harvest methods on ascorbic acid, NO₃-N, chlorophyll content of leaf lettuce.

Harvest method	Ascorbic acid (mg/100 g FW)	NO ₃ -N (ppm)	Chlorophyll ^z
Reaping ^y	44	2.277	18.3
Conventional	42	2.492	19.1
	NS ^x	NS	NS

^z Measured with SPAD-502 (MINOLTA).

^y Data from 2nd reaping harvest.

^x NS, not significant (P>0.05).

Table 2. Effects of location and cultivar on the vegetative growth parameters of Jerusalem artichoke in 1998 and 1999 season. Source: Jones et al., 1990.

Location	1998			1999		
	Cultivar		Mean	Cultivar		Mean
	Fuseau	Local		Fuseau	Local	
	Plant height (cm)					
El-Kaluobia	123.7 c ¹	241.2 a	182.5 A	147.5 b	230.0 a	191.2 A
El-Behiara	118.8 c	172.2 b	145.0 B	120.2 c	163.8 b	141.9 B
Mean	121.2 B	206.2 A		133.9 B	196.9 A	
	Main shoot diam. (cm)					
El-Kaluobia	1.2 a	1.6 a	1.4 A	1.3 a	1.7 a	1.5 A
El-Behiara	1.2 a	1.4 a	1.3 A	0.6 a	1.3 a	0.9 A
Mean	1.2 a	1.6 A		1.0 B	1.5 A	
	No. main shoots per plant (each)					
El-Kaluobia	9.0 a	7.8 a	8.4 A	5.0 a	5.0 a	5.0 A
El-Behiara	5.2 a	7.0 a	6.1 A	7.8 a	3.2 a	4.2 A
Mean	7.1 A	7.4 A	7.4 A	5.1 A	4.1 A	
	Fresh wt. (g/plant)					
El-Kaluobia	1.4 a	5.0 a	2.7 A	1.6 a	2.9 a	2.2 A
El-Behiara	0.6 b	2.3 b	1.4 B	0.4 a	1.0 a	0.7 B
Mean	1.0 B	3.6 A		1.0 B	1.9 A	

¹Means separation at 5% level (DMRT); capital letters between mean values, small letters between location values.

Figures

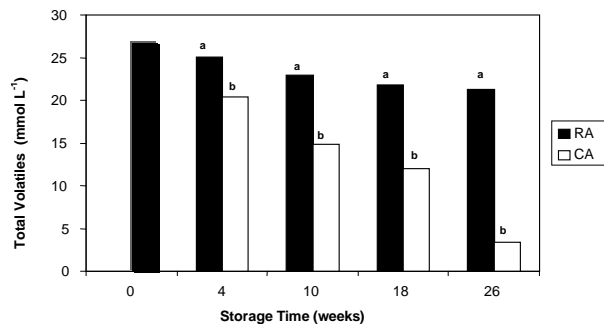


Fig. 1. Total volatiles from juice of 'Pacific Rose' apples after storage in RA and CA for up to 26 weeks at 0°C.

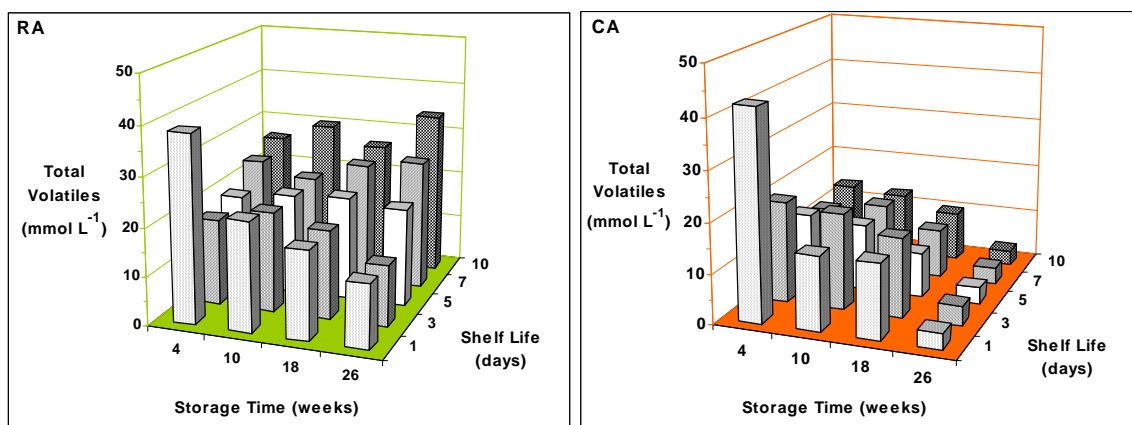


Fig. 2. Total volatiles in 'Pacific Rose' apples during 10 days shelf life at 20°C after storage in RA or CA for up to 26 weeks at 0.5°C.

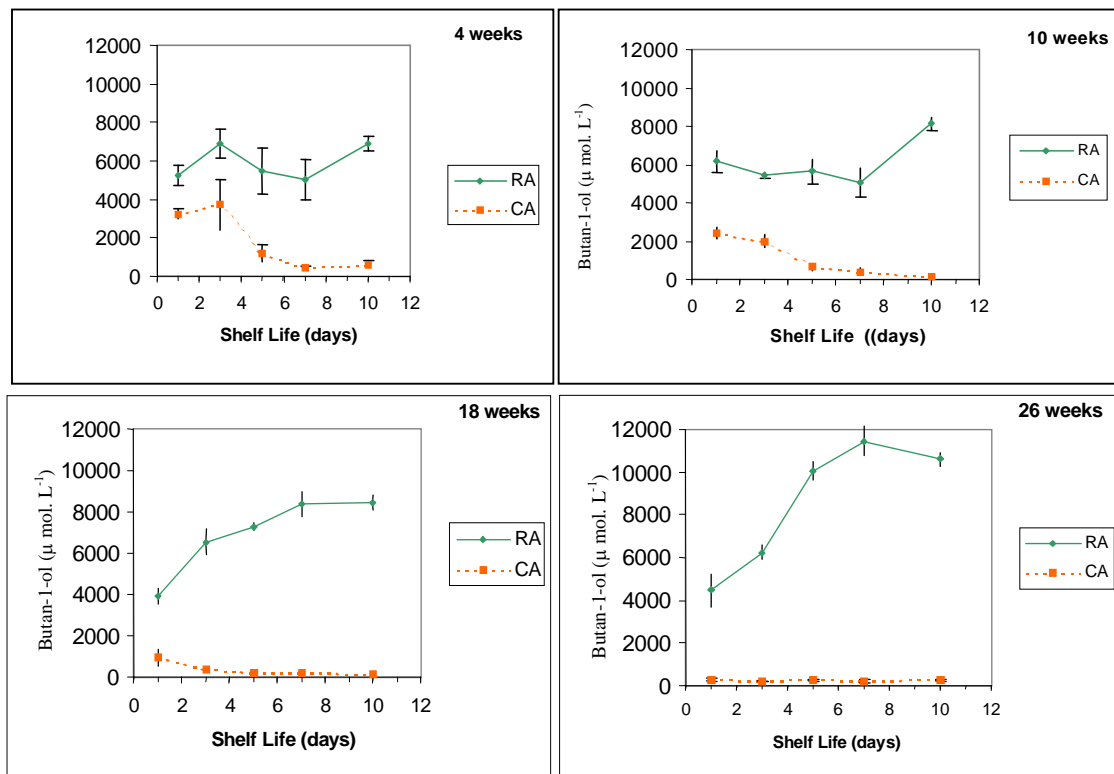


Fig. 3. Butanol concentrations in juice of 'Pacific Rose' apples through 10 days at 20°C following storage for up to 26 weeks in RA or CA at 0.5°C.

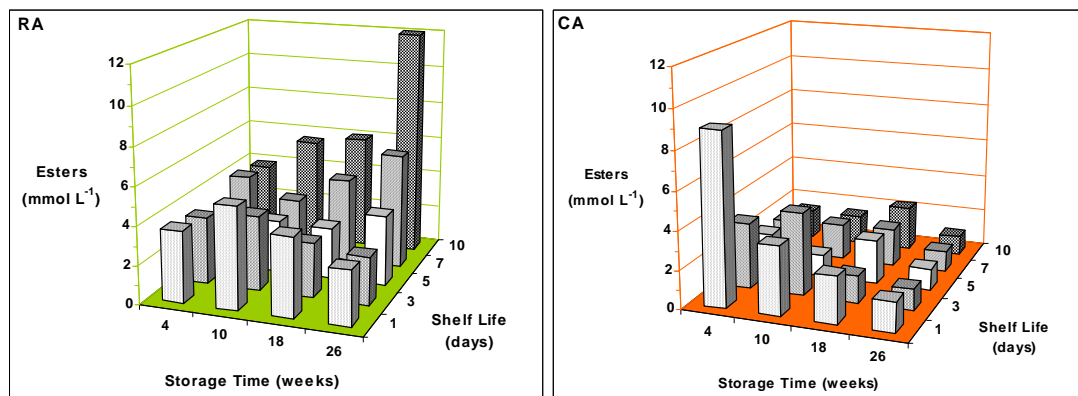


Fig. 4. Total ester concentration in juice of 'Pacific Rose' apples after removal from RA and CA storage at 0.5°C and during 10 days at 20°C.