DYNAMIC CONTROLLED ATMOSPHERE STORAGE OF AVOCADOS: TECHNOLOGY FOR MANAGING EXPORTS?

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ABSTRACT

Refrigerated storage provides only a limited storage life that constrains the export markets that can be reached. Storage life may be extended with controlled atmosphere storage (CA), which may be operated as a dynamic (DCA) or static (SCA) system. The quality of New Zealand-grown 'Hass' avocados has been compared following storage in DCA or SCA for 6 weeks at 5°C. DCA-stored fruit ripened more rapidly than SCA-stored fruit, 4.9 and 7.3 days, respectively, and in approximately the same time as air-stored fruit. The rapid ripening of DCA-stored fruit made them more uniform in ripeness than SCA-stored fruit. When ripe, DCA-stored fruit had a lower incidence of a range of disorders, including stem end and body rots, than SCA-stored fruit. These findings suggest that DCA is a useful technology for the storage of avocados, for both prolonging storage and improving quality, and may have a role in managing New Zealand avocado exports.

Keywords: DCA, quality, cholorphyll fluorescence, *Persea americana*

INTRODUCTION

Refrigerated storage provides a storage window of about four weeks, which limits the range of export markets that can be reached. Consequently there is interest in the use of controlled atmosphere (CA) storage to extend the storage period and the range of markets that can be reached with the fruit still in good condition. General recommendations for storage of avocado fruit under CA exist, with suggested atmospheres in the range 2 to 5% O_2 and 3 to 10% CO_2 (Kader, 2001; Thompson, 1998). However, conditions for the CA storage of New Zealand grown 'Hass' avocados are only now being determined.

CA storage may be achieved using static (SCA) or dynamic (DCA) systems. In SCA, the O_2 level is maintained at a pre-determined level throughout the storage period. In DCA, O_2 levels are determined by a low O_2 stress response from the fruit, which may change during storage. DCA therefore allows greater optimisation and matching of storage conditions to the fruit tolerance to low O_2. Operating CA at the lowest safe O_2 level also provides a means of maximising the CA response from low O_2 atmospheres whilst avoiding high CO_2, which may reduce ripe fruit quality (Burdon *et al.*, 2008).

The operation of DCA storage is dependent on having a sensor that can detect low O_2 stress in the fruit. Changes in fluorescence emitted from the chlorophyll in the fruit skin in response to low O_2 stress can be identified by the fluorescence interactive response monitor (FIRM) from Isolcell, Italy (formerly available as HarvestWatch™ sensor). Before establishing CA conditions, the sensor is placed over a sample of fruit and the container holding the fruit and sensor is placed in the CA room. If fruit from more than one orchard are to be stored in the room, samples of fruit from each orchard can be put under separate sensors. The sensor is connected to a computer and the fluorescence response throughout storage is monitored using the ISOSOFT software. At the start of DCA storage, the O_2 level is decreased until low O_2 stress is detected, and the O_2 level is then increased sufficiently to alleviate the stress. The increase in O_2 after detecting low O_2 stress is termed 'backing–off' and sets the safe O_2 level for storage. The cycle of stress measurement and backing-off is repeated at intervals through the storage period.

In this paper, the benefits to fruit quality of DCA over SCA, and the overall benefit of CA over air storage, are illustrated using data from a trial in which fruit from four orchards were stored in DCA, SCA or air (Burdon *et al.*, 2008). Fruit quality was assessed after six weeks of storage at 5°C and also after ripening at 20°C.

MATERIALS AND METHODS

Fruit

'Hass' avocado (*Persea americana*) fruit (count size 20-25) were harvested from 4 commercial orchards in the Bay of Plenty, New Zealand on 4 December 2006. The dry matter contents of the fruit from the four orchards were between 30 and 36%. Ungraded fruit from each orchard were allocated randomly into DCA or SCA treatments, with 200-240 fruit per orchard per treatment. Additional samples of 50-60 fruit per orchard were held in air to contrast with the CA treatments. Fruit were cooled to 5°C overnight before establishing the CA treatments.

Treatments

DCA (<3% O_2/0.5% CO_2) and SCA (5% O_2/5% CO_2) atmospheres were established in 0.4 m^3 chambers (David Bishop Instruments, DBI) and maintained for 6 weeks at 5°C. In SCA, 5% CO_2 was reached after approximately 5 days. Atmospheres in each chamber were maintained automatically using a DBI Oxystat 2 control system. Ethylene was removed by passing the atmospheres continuously through platinum catalyst ethylene scrubbers. Oxygen stress in fruit under DCA was assessed by FIRM sensors placed over a sample of 12-15 fruit from each orchard in the chamber. The level of O_2 maintained in DCA was approximately 1% above the stress threshold of fruit from the most sensitive orchard.

Assessments

Fruit quality assessments were made according to the criteria in the New Zealand Avocado Industry Council Fruit Assessment Manual (Dixon, 2003). Fruit were assessed immediately after removal from storage and also after ripening at 20°C. Immediately after storage, fruit were inspected for fruit skin colour (0-100 scale where 0=bright glossy green, 30=olive green, 60=wood brown, 80=purple brown and 100=dull black) and any visible skin defects (fuzzy patches, FP; discrete patches, DP; and external rots, ER). Fuzzy patches were considered fungal in origin, whereas DP are physiological. Fruit were then held at 20°C to ripen. Fruit were assessed daily for firmness by hand squeeze. Once the fruit had reached eating ripeness, determined by hand squeeze to be equivalent to a firmness reading of at least 85 using a Firmometer with a 300g weight, they were assessed for skin colour and external rots and cut to assess ripe fruit disorders (stem end rots, SER; body rots, BR; and vascular browning, VB). Each disorder was scored as present or absent, and where present, severity was rated on a 0-100 scale for the area of the fruit affected. Diffuse flesh discoloration (DFD) was recorded as present or absent when ripe with no severity score.

Statistical analysis

Mean values for skin colour and days to ripen were subjected to analysis of variance (ANOVA) using Genstat Release 8.2 (PC/Windows XP) Copyright 2005, Lawes Agricultural Trust, Rothamsted Experimental Station. Mean disorder incidences were first arcsin(sqrt(x)) transformed prior to ANOVA. Analysis for effects of treatments on disorder incidence was conducted using the total disorder incidence, irrespective of severity, with the untransformed disorder incidence data presented in the results. Each orchard was treated as a replicate.

RESULTS

At the end of storage, the skin colour of both SCA- and DCA-stored fruit was markedly less advanced than that of air-stored fruit, but with DCA-stored fruit showing slightly more colour change than SCA-stored fruit (Table 1). The predominant disorder at the end of storage was FP, with a significantly higher incidence in SCA- than DCA-stored fruit. Compared with FP, the incidence of DP was low at <2%, with less DP in SCA-stored than

DCA-stored fruit. The incidence of ER was significantly lower in both DCA and SCA than in air-stored fruit .

After 6 weeks of storage, DCA-stored fruit ripened faster than SCA-stored fruit, 4.9 and 7.3 days, respectively (Table 2). The time for DCA fruit to ripen was similar to that for fruit that had been stored in air. SCA-stored fruit had a significantly higher incidence of all disorders, except DFD, than DCA-stored fruit (Table 2). The incidence of all disorders, except ER, was higher in air-stored fruit than in either DCA or SCA. DFD was only seen to any significant extent in air-stored fruit. The ripe fruit skin colour from all treatments was very similar.

Table 1. Skin colour and disorder (fuzzy patches, FP; discrete patches, DP; external rot, ER) incidence in 'Hass' avocado fruit stored for 6 weeks at 5°C under static (SCA; 5% O_2 / 5% CO_2) or dynamic (DCA; <3% O_2 / 0.5% CO_2) controlled atmosphere conditions, or air. Values are the means of samples from 4 orchards.

Storage	Skin Colour	Disorder incidence (%) FP	DP	ER
Air	48	3	1	4
SCA	3	29	0	1
DCA	11	4	2	1
Statistical analysis: ANOVA P values				
Air v. CA	<0.001	0.054	0.514	0.109
SCA v. DCA	<0.001	<0.001	0.001	0.762

DISCUSSION

Storage in DCA resulted in better ripe fruit quality than storage in SCA, and both DCA and SCA were better than air. The skin colour change of DCA-stored fruit was not slowed during storage to the same extent as that of SCA-stored fruit, but both were less advanced than air-stored fruit. DCA- and air-stored fruit ripened in a similar time, whereas SCA-stored fruit ripened more slowly. Overall, rot incidence was higher in air than CA-stored fruit, and higher in SCA- than DCA-stored fruit. Storage in DCA or SCA prevented DFD expression, in contrast to the high incidence in air-stored fruit.

A prolonged ripening period after storage provides greater opportunity for rots to develop as the fruit ripens (Hopkirk *et al.*, 1993). In DCA-stored fruit, the ripening time was the same as for air-stored fruit, but the incidence of rots was lower. This suggests that DCA storage conditions reduce the expression of rots directly, rather than simply by altering the ripening time. Adding ripening time to storage time gives the fruit age from harvest. Fruit quality has been reported to deteriorate when fruit age exceeds 32 days (Dixon *et al.*, 2003a). Hence quality can be maintained by keeping fruit age below 32 days, but this limits the range of export markets that can be reached. DCA alters the fruit age / quality relationship from that seen in air storage, allowing an increase in fruit age without the associated increase in disorders.

Table 2. Time to ripen, skin colour when ripe and disorder (stem end rot, SER; body rot, BR; external rot, ER; vascular browning, VB; diffuse flesh discoloration, DFD) incidence in 'Hass' avocado fruit stored for 6 weeks at 5°C under static (SCA; 5% O_2 / 5% CO_2) or dynamic (DCA; <3% O_2 / 0.5% CO_2) controlled atmosphere conditions, or air. Fruit were ripened in air at 20°C after storage. Values are the means of samples from 4 orchards.

Storage	Time to ripen	Skin Colour	SER	Disorder incidence (%) BR	ER	VB	DFD
Air	4.8	78	79	88	23	95	62
SCA	7.3	82	57	52	29	49	0
DCA	4.9	81	35	29	6	29	1
Statistical analysis: ANOVA *P* values							
Air v. CA	<0.001	<0.001	<0.001	<0.001	0.272	<0.001	<0.001
SCA v. DCA	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	0.267

The overall benefit from DCA is through maximising the effect of low O_2 and avoiding the detrimental effects of high CO_2. High CO_2 has been shown to cause slower and less synchronous ripening and an increased incidence of rots (Burdon *et al.*, 2008). Skin colour change during ripening is slowed markedly by a reduction in O_2 from 5 to 3%, and is slowest at 1-2% O_2 (Hertog *et al.*, 2003). Whether it is the low O_2 concentration, or the act of checking the low O_2 stress point and backing-off that results in the good performance of DCA-stored fruit is not yet clear. However, with a low O_2 stress point of 1-2% O_2, it appears that even for static CA, an O_2 level lower than 5% may be appropriate.

A major storage quality problem for New Zealand-grown fruit is rots. Even when conducting trials with fruit from 4-5 orchards, large differences in the rot incidence in fruit from individual orchards are often seen. This suggests that the selection of low rot-risk fruit is important in obtaining a good out-turn after prolonged storage. Likewise, using fruit too early or late in the season is also going to increase the risk of a poor out-turn after prolonged storage (Dixon *et al.*, 2003b).

CONCLUSIONS

Fruit quality was better after CA storage than after air storage, and that DCA storage was better than SCA. DCA independently reduces the time to ripen after storage and the incidence of rots when ripe. The ability to store fruit for longer with lower disorders raises the possibility of holding fruit in New Zealand prior to export, supplying exports out of stored inventory, and also for exporting to more distant markets.

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