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Controlled and modified atmospheres to extend storage life of avocados

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SYNOPSIS
Fuerte avocados often arrive on the overseas markets in a soft and overripe condition. This can be prevented by controlled atmosphere storage in 2 per cent O_2 + 10 per cent CO_2 at 5,5°C or by CO_2 treatment of 25 per cent for three days, commencing one day after harvest.

INTRODUCTION

Optimum controlled atmosphere (CA) conditions for avocados are 2 per cent oxygen (O_2) and 10 per cent carbon dioxide (CO_2) at a fruit temperature of 7,2°C (Reeder & Hatton, 1970). Spalding & Reeder (1972) reported that the length of the storage period can be doubled under these conditions, but that a temperature of 4,5°C resulted in 100 per cent chilling injury. These findings were confirmed in South Africa (Eksteen & Truter; 1983) and it was also shown that CA storage decreased the risk of chilling injury considerably. Chilling injury was also controlled by exposure to CO_2 concentrations of 20 to 25 per cent for three to five days at a temperature of 5,5°C.

Areas in South Africa where avocados are produced are situated in Natal along the east coast and as far north as Louis Trichardt in Transvaal. Packed and precooled fruit are transported by refrigerated road or rail transport to Cape Town harbour, some 2 000 km away, for export by sea to the United Kingdom and European markets. The journey by sea takes about 24 days and the time between harvesting and arrival overseas may be as long as 28 days. During some seasons problems are experienced with soft fruit on the overseas markets. Lowering of the shipping temperature to overcome this problem is not feasible due to the danger of chilling injury.

The objective of this study was to develop methods to extend the storage life of avocados to enable growers to export and market avocados successfully on overseas markets.

MATERIAL AND METHODS

Class 1 fruit of the cultivar Fuerte was used in the study. Fruit were harvested at optimum picking maturity (±70 per cent moisture content) and precooled. The following

treatments were applied after packing into single layer cartons, after which fruit were stored for 35 days at 5,5°C.

1.1 Controlled atmosphere (CA) storage in 2 per cent O_2 + 10 per cent CO_2 (CA conditions were reached five days after harvest and total period under CA was 30 days).

1.2 Carbon dioxide (CO_2) applied one day after harvest in a gastight container (initial concentration of 25 per cent CO_2). Three days later fruit were removed and stored under regular atmosphere (RA) conditions for the remainder of the storage period (32 days).

1.3 Carbon dioxide treatment five days after harvest at a concentration of 20 per cent for a period of three days. Oxygen and CO_2 concentrations were maintained at 2 and 20 per cent respectively. Treated fruit were stored under RA conditions for the remainder of the storage period (30 days).

1.4 Single fruit were packed into small polyethylene bags (25 micron thick) which were closed by twisting and folding the open end once before being packed into a carton. The bags were opened again after storage, prior to ripening.

1.5 Samples of 14 fruits were packed into large polyethylene bags in cartons. The bags were closed by folding the open end before closing the carton and were opened again prior to ripening.

1.6 Control fruit were packed into ventilated single layer cartons.

TABLE 1 Effect of regular (RA) controlled (CA) and modified atmosphere on the quality of Fuerte avocados at the eating ripe stage after 35 days storage at 5,5°C and 4 to 10 days at 20°C

Treatment	Days at 20°C to ripen	Anthracnose rot (%)	Chilling injury (%)	Grey flesh (%)	Vascular browning (%)
Control (regular atmosphere)	4	1,2 a	25,9 a	15,8 a	4,0 a
CA Storage (2% O_2 + 10% CO_2)	7	15,0 b	0,4 b	0,9 b	5,4 a
CO_2 treatment 1 day after harvest[1]	4	0,0 a	0,5 b	1,7 b	1,9 b
CO_2 treatment 5 days after harvest[2]	6	2,4 a	9,1 cd	9,5 c	4,0 a
Single fruit in small polybags	7	6,5 c	6,6 d	6,2 c	6,0 a
Polybag in carton	10	25,6 d	11,6 c	10,2 c	16,3 c

[1] 25 per cent CO_2 for three days. Oxygen concentration decreased to less than 1 per cent after three days and CO_2 concentration increased to 35 per cent.

[2] 20 per cent CO_2 for three days. Oxygen concentration was maintained at 2 per cent and CO_2 concentration at 20 per cent.
Figures in columns followed by the same letter do not differ significantly at P = 0,05 according to Duncan's Multiple Range Test.

TABLE 2 Effect of controlled and modified atmosphere storage on the incidence of pulp spot in Fuerte avocados.

Treatment	Pulp spot(%)
Control (regular atmosphere)	14,4 a
CA storage in 2% O_2 + 10% CO_2	0,0 b
25% CO_2 for 3 days commencing 1 day after harvest	4,8 b
Single fruit in polybags	1,9 b

Figures followed by the same letter do not differ significantly at P = 0,05 according to Duncan's Multiple Range Test.

Fruit were ripened at 20°C in regular atmosphere after storage. Sample size for CA treatments were 20 cartons containing 14 fruits each and six cartons containing 14 fruits each for the other treatments and control.

Quality assessment
The fruit were evaluated after ripening at 20°C. The number of days taken to reach the eating ripe stage were noted and the number of fruit showing anthracnose rot, chilling injury, grey flesh, pulp spot and vascular browning were expressed as percentages (Truter & Eksteen, 1982).

Results were subjected to analyses of variance and means were separated using Duncan's multiple range test (Snedecor & Cochran, 1969).

RESULTS
The time taken to reach the eating ripe stage varied from four to 10 days (Table 1). Control fruit and those treated with CO_2 one day after harvest ripened within four days at 20°C. CA storage in 2 per cent O_2 + 10 per cent CO_2 and polyethylene bags extended the ripening period to 10 days, but this led to the development of anthracnose rot. The highest incidence (25,6 per cent) was found in fruit stored in large polyethylene bags. In fruit where the ripening time was only four days, the incidence of anthracnose rot was low (1,2 per cent and 0 per cent respectively).

Chilling injury (25,9 per cent) developed in the control fruit and in those packed in large polyethylene bags (11,6 per cent), but was almost completely prevented by CA storage in 2 per cent O_2 + 10 per cent CO_2 (0,4 per cent) and CO_2 treatment one day after harvest (0,5 per cent) (Table 1).

The incidence of grey flesh followed almost the same trend as was observed for chilling

injury. The highest incidence of this disorder was found in control fruit (15,8 per cent) while CA storage and CO_2 treatment one day after harvest effectively delayed its development (Table 1).

The highest incidence of vascular browning (16,3 per cent) was found in fruit packed in large polyethylene bags, but only 1,9 per cent occurred in the fruit which received CO_2 treatment one day after harvest (Table 1).

The incidence of pulp spot was significantly decreased by CA storage in 2 per cent O_2 + 10 per cent CO_2 (0 per cent), CO_2 treatment one day after harvest (4,8 per cent) and single fruit packed into small polyethylene bags (1,9 per cent) (Table 2).

DISCUSSION

For orderly marketing of South African avocados on overseas markets fruit should ripen within four to five days after discharge from the ship and should preferably be sold and consumed before the next consignment arrives. From the results in Table 1 it can be seen that the fruit of only two treatments complied with these requirements.

CA storage in 2 per cent O_2 + 10 per cent CO_2 increased the shelf-life of avocados to 10 days but with a concomitant increase in anthracnose rot. This confirmed results previously reported by Eksteen & Truter (1983) and is also one of the reasons why a ripening period of four days is preferred. If any of the latter treatments are thus considered for commercial application, an effective disease control programme would have to be followed.

Low shipping temperatures (5,5°C) are essential for sea export, but chilling injury then becomes a major problem, especially early in the season (Spalding & Reeder, 1972; Swarts, 1982; Eksteen & Truter, 1983). Chilling injury was prevented by CA storage in 2 per cent O_2 + 10 per cent CO_2 and CO_2 treatment one day after harvest. However, CA storage delayed ripening for too long to be of any practical value. Under local conditions a CO_2 treatment one day after harvest, prior to or during transport to Cape Town, may be a practical method to prevent chilling injury during the subsequent shipping period.

Grey flesh is associated with senescence (Swarts, 1984). The disorder was successfully controlled by CA storage and CO_2 treatment one day after harvest.

Vascular browning is associated with decay because the vascular tissue is infected by fungi causing stemend and anthracnose rot (Swarts, 1984). Long shelf-life periods such as 10 days, therefore resulted in an increase in the incidence of this disorder.

Pulp spot is another serious disorder of Fuerte avocados in South Africa. However, the incidence and severity varies from season to season. Symptoms become visible after the cut surface of the fruit has been exposed to the atmosphere for about 10 minutes. It mainly occurs near the stemend of the fruit as round spots on the cut vascular tissue (Swarts, 1984). The disorder was significantly decreased by CA storage in 2 per cent O_2 + 10 per cent CO_2, CO_2 treatment one day after harvest and packing of single fruit in

small polyethylene bags.

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