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EFFECTS OF CONTROLLED AND MODIFIED ATMOSPHERE STORAGE ON QUALITY OF EATING RIPE AVOCADOS

G J EKSTEEN & A B TRUTER
FRUIT AND FRUIT TECHNOLOGY RESEARCH INSTITUTE, STELLENBOSCH

OPSOMMING

Fuerte, Edranol en Mass avokados wat onder beheerde atmosfeer toestande met 2% O + 10% CO_2 en teen 5,5°C opgeberg was, was van beter loestande wat beide uiterlike voorkoms en interne gehalte betref as vrugte wat teen dieselfde temperatuur en nórmale atmosfeer geberg is. Antraknose-vrot het egter 'n probleem geword by vrugte wat onder die beheerde atmosfeer opgeberg is weens die langer period van opberging by 20°C wat nodig is om die vrugte eetryp te maak.

Verpakking in poliëetiléen sakkies het ook 'n verbetering in kwalitiet van vrugte na opberging tot gevolg gehad hoewel temperatuur hier van groot belang was. Hierdie verpakkingsstelsel is ekonomies aanvaarbaar veral wanneer vrugte afsonderlik in klein sakkies verpak word wat dan toegevou word om die vrug te seel. Vrugte moet egter in 'n nórmale atmosfeer teruggeplaas word gedurende die rypmaak-proses om beskadiging te voorkom.

Skokbehandeling met CO_2 (25% CO_2 vir 3 dae by 5,5°C) het belowende resultate gelewer maar vereis verdere ondersoek.

SUMMARY

Fuerte, Edranol and Mass avocados stored under CA conditions of 2 percent O_2 and 10 percent CO_2, at 5,5°C were superior in both external appearance and internal quality to those stored at the same temperature but at normal atmosphere conditions. Anthracnose decay became a problem with CA stored fruit because of the longer storage at 20°C required for the fruit to reach the eating ripe stage.

Packing in polyethylene bags also improved fruit quality although temperature plays the major role. This packing system is economically feasable especially when individual fruits are packed in small polyethylene bags which are then folded to seal the fruit. Normal atmosphere should however be restored when the fruit is subjected to ripening temperatures to prevent injury. A CO_2 shock treatment (25% CO_2 for 3 days at 5,5°C) showed very promising results but requires further investigation.

INTRODUCTION

Recent studies by Truter and Eksteen (1982) and Eksteen and Truter (1983) in improving the storage and shelf life of avocados, have shown that storage at 5,5°C in a controlled atmosphere (CA) of 2% O_2, + 10% CO_2, gave significant improvements in shelf life. The incidence of anthracnose as post-harvest decay however increased under these conditions, thus causing loss of quality (Truter and Eksteen, 1982).

Absorption of ethylene and addition of carbon monoxide did not affect fruit quality under storage but different types of packing material and wax treatments did affect keeping qualities and ripening (Truter and Eksteen, 1982; Eksteen and Truter 1983).

The present paper reports on studies of the effects of storage under CA, regular atmosphere (RA) and different ways of packing in polyethylene bags on the shelf life and quality of eating ripe avocados.

METHODS AND PROCEDURES

1. Controlled atmosphere storage of Fuerte, Edranol and Hass avocados

Fruit of these varieties were harvested at the optimum maturity (12% oil content) and stored for 33 days at 5, 5°C. The following CA conditions were applied:

1.1. Fuerte 2% O_2 + 10% CO_2; 1 % O_2 + 10% CO_2 and 2% O_2 + 3% CO_2.

1.2. Edranol and Hass 2% O_2 + 10% CO_2

2. Packing of Fuerte

Treatments

2.1 The fruit were packed in a polyethylene bag (25µm) in a carton. The bag was opened after 33 days storage at 5,5°C.

2.2 The fruit were packed in a polyethylene bag (190 µm) in a carton and CO_2 was introduced to reach levels of 6, 12 and 18%. The bags were opened to restore normal atmosphere after 6 days at 5,5°C and stored for a further 27 days.

2.3 Fruit were individually packed into small polyethylene bags (25µm) which were closed by folding before packing into a carton.

2.4 Fruit were individually packed into small polyethylene bags (25µm) but the bags were heat sealed before packing into a carton.

3. Comparative experiments with CA, RA, $C0_2$ treatment and polyethylene packing on Fuerte

3.1 The same procedure as for CA experiments (par. 1) was followed but only the 2%. O_2 + 10% CO_2 combination was used.

3.2 CO_2 shock treatments (15, 20, 25 and 30% CO_2) were applied at harvest (par. 2.2) but the bags were opened after 3 days at 5,5°C.

3.3 CO_2shocktreatments(15, 20, 25 and 30% CO_2) were applied 4 days after harvest (on arrival in Cape Town) and the bags were opened after 3 days at 5,5°C.

3.4 Single fruit were packed in small polyethylene bags (par. 2.3). The bags were opened after storage (prior to ripening).

3.5 The fruit were packed into polyethylene bags (25µm) in cartons. The bags were folded closed before closing the carton and were opened again after storage.

4. Control fruit for all the above treatments were picked on the same day from the same orchard. After grading and sorting they were packed into ventilated single layer cartons and then stored at 5,5°C for 33 days and ripened at 20°C.

5. Evaluation of fruit quality was carried out according to the method described by Truter and Eksteen (1982) at the eating ripe stage.

6. Experimental design and analysis

Each C A treatment consisted of 20 cartons containing 12 fruits each. Six cartons containing 12 fruit each were used for each packing treatment. All zeros were excluded from the analysis of variance because inclusion led to heterogeneity of variances.

RESULTS AND DISCUSSION

After 33 days storage at 5, 5°C (total shipping period to Europe) under different CA conditions, the fruit were evaluated. The effect of these conditions on quality of Fuerte, Edranol and Hass avocados at the eating ripe stage are given in Table 1. From this data it is clear that the shelf life (number of days at 20°C to ripen) is almost doubled by CA storage. The longer period required to reach this eating ripe stage is the main cause for the big increase of anthracnose rot in CA stored fruit. Fuerte fruit, despite large variations, stored at 1 percent O_2 + 10% CO_2, developed significantly more anthracnose than control fruit. This may also be due to low O_2 injury as described by Smock (1979) with apples, the damaged cells being more susceptible to anthracnose rot during the shelf life period at a higher temperature. Increased anthracnose rot with CA storage was also reported in Florida (Mutton and Reeder, 1972, Spalding and Reeder, 1972). This indicates the importance of an efficient preharvest spray programme and post-harvest procedures to limit infection.

It is also clear from Table 1 that CA storage improves the quality of avocados. Fuerte stored at 5,5°C in regular atmosphere (RA) developed 77,2 percent chilling injury, but this disorder was totally absent in similar fruit stored in CA.

Pulp spot developed in almost 56% of the RA stored fruit and in almost 19%of fruit stored at 2% O_2 + 3% CO_2 (Table 1). Pulp spot was however totally absent when the storage atmosphere contained 10% CO_2, This indicates that CO_2 is an important factor in controlling pulp spot in avocados and confirms earlier results reported by Truter and Eksteen (1982).

The effects of storage in polyethylene bags and CO_2 shock treatments on the fruit quality of Fuerte avocados are shown in Table 2.

The results obtained with Fuerte avocados, packed in polyethylene bags in cartons and stored at 5,5°C for 33 days before ripening at 20°C, show that packing of fruit in this manner extended the shelf life of the fruit but also resulted in an increase in anthracnose rot. This is probably due to a higher relative humidity (RH) within the bag and the longer period at 20°C to acquire the eating ripe stage. This confirms similar results obtained in Australia by Oudit and Scott (1973) on Mass avocados stored at 10°C.

The absence of chilling injury in the polyethylene bag packs (and in CA storage) is not clear because all the fruit were stored at a pulp tempera ture of 5,5°C. Effective control of chilling injury by wrapping the fruit in cellophane is also reported (Swarts, 1979) but no explanation for this reaction is given. It can however be postulated that desiccation of the cells in the skin of the fruit is reduced by the polyethylene bag, cellophane wrappers or a higher RH in the CA store. This may result in the retention of cell stability and therefore a lower rate of phenolic oxidation which is the main cause of the discoloration associated with chilling injury.

After 33 days at 5,5°C and CO_2 concentration in the large polyethylene bags (25µm), containing 12 fruits each (treatment 2,1), leveled off at 4%. In the small poly-ethylene bags (25µm), containing single fruits, (treatments 2.3 and 2.4), 8% CO_2 was measured after 33 days at 5,5°C. The different CO_2 concentrations of 6, 12 and 18% applied (treatment 2, 2) in the thicker (190µm) polyethylene bags increased to 14, 21 and 33% respectively after 6 days at 5,5°C.

It is clear from Table 2 that pulp spot was reduced by packing methods which allow CO_2 to accumulate in the atmosphere surrounding the fruit. Lowest pulp spot figures were recorded within fruit individually packed into polyethylene bags, thus confirming results given above. Fruit treated with 6 and 18% CO_2, for 6 days, developed more grey spot. With both disorders CO_2 concentration and time of exposure may be important factors.

Practical and economical considerations demand the most feasable method of handling and storage to obtain the best shelf life and eating quality. To consider all these options, the most promising treatments found in this investigation were combined into one experiment. The results obtained with Fuerte avocados are summarized in Table 3.

the exposure to high CO_2, concentrations appears to be critical. A 3 day exposure decreased grey spot incidence but 6 day exposure caused an increase due to CO_2 injury. This injury is due to senescence which was also reported in Bartlett pears (Fiddler and North, 1966).

The lower incidence of anthracnose rot was due to effective preharvest control carried out during that season.

The results of the present investigation show that CA storage improves shelf life and fruit quality of avocados if applied soon after harvest. Careful control of the O_2, and CO_2, content of the CA is essential and requires the use of gas tight containers with accurate control systems to be available at the production point. At present such containers are expensive and not readily available so that provision of CA for storage during transport is neither economical nor practical at present.

CO_2 shock treatment immediately after harvesting holds many practical advantages but duration as well as CO_2, concentration and CO_2/O_2, ratios require further investigations.

Although packing of avocados in polyethylene bags in cartons or individually in small bags sealed by folding gave improved post storage quality comparable to that obtainable by CA storage, removal of these bags prior to submitting fruit to ripening temperatures, presents serious handling problems in practice.

TABLE 1 - The effect of controlled atmosphere storage at 5,5°C for 33 days on the quality* of Fuerte, Edranol and Hass avocados at the eating ripe stage.

Treatment	Days at 20°C to ripen	Anthracnose %	Chilling injury %	Grey spot %	Pulp spot %
Fuerte					
Control (RA)	4-7	25,2 a	77,2	3,3 a	55,9 a
1.1 2% O_2 + 10% CO_2	10-14	38,5 ab	0	8,6 a	0 ★1
1% O_2 + 10% CO_2	10-14	54,2 b	0	15,9 a	0 *I
2% O_2 + 3% CO_2	10-14	41,0 ab	0	6,6 a	18,9 b
Edranol					
Control	3-4	0 *I	0	23,7 a	4,1
1.2 2% O_2 + 10% CO_2	5-8	26,5	0	2,66 b	0 ★1
Hass					
Control	3-4	0 *I	0	22,5 a	0 *I
1.2 2% O_2 + 10% CO_2	5-8	2,2	0	4,4 b	0 ★1

* Values followed by the same letters do not differ significantly at P = 0,05
*I Excluded from analysis

TABLE 2 - The effect of packing in polyethylene bags prior to storage 5,5°C for 33 days on the quality* of Fuerte avocados at the eating ripe stage

Treatment	Days at 20°C to ripen	Anthracnose %	Chilling injury %	Grey spot %	Pulp spot %
Control (RA)	4-7	25,2 a	77,2 a	3,3 a	55,9 a
2.1 Polybag in carton	7-10	92,0 c	0 *I	3,8 a	36,6 ab
2.2 6% CO_2 in polybag	4-7	40,1 ab	1 b	27,1 b	41,3 ab
2.2 12% CO_2 in polybag	4-7	33,8 a	1,7 b	8,3 ab	15,7 b
2.2 18% CO_2 in polybag	4-7	66,2 b	0 *I	16,8 ab	8,3c
2.3 Small Polybag folded	5-8	28,8 a	0 *I	0 *I	6,6 c
2.4 Small Polybag sealed	5-8	58,0 b	0 *I	2,9 a	6,8 c

* Values followed by the same letters do not differ significantly at P = 0,05

*I Excluded from analysis

2.1 Big polyethylene bag (25µm) in carton, folded and taped after packing (bags opened after 33 days at 5,5°C - CO_2 stabilised at ± 4 percent

2.2 CO_2 introduced into big polyethylene bag after packing to a level of 6 percent, 12 percent and 18 percent in the atmosphere (bags opened after 6 days at 5,5°C - CO_2 stabilized at 14, 21 and 33 percent respectively)

2.3 Fruit packed individually into a small polyethylene (25µm) bag which was then folded over, or

2.4 Heat sealed before packing into a carton (bags opened at eating ripe stage — CO_2 stabilized at ± 3 percent)

TABLE 3 The effect of regular (RA) and controlled (CA) atmosphere storage, carbon dioxide (CO_2) treatments and polyethelene bag packaging on the quality★ of Fuerte avocados at the eating ripe stage after storage for 33 days of 5,5°C.

Treatment	Days at 20°C to ripen	Anthracnose %	Chilling injury %	Grey spot %	Vascular Browning %
Control (RA)	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 shock ★1 1 day after harvest	4	0	0,5 b	1,7 b	1,9 b
CO_2 shock ★2 4 days after harvest	6	2,4 a	9,1 cd	9,5 c	4,0 a
Single fruit packed in polybag	7	6,5 c	6,6 d	6,2 c	6,0 a
Carton lined with polybag	10	25,6 d	11,6 c	10,2 c	16,3 c

★ Figures followed by the same letter do not differ significantly at P = 0,05
★1 Start at 18% O_2; 20% CO_2 finished at 0% O_2; 29% CO_2 after 3 days
★2 Maintained at 18% O_2, 20% CO_2 for 3 days

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