South African Avocado Growers' Association Yearbook 1995. 18:85-88

Modified Atmosphere Shock Treatment and an Orchard Mulching Trial for Improving Fuerte Fruit Quality

M.E. Allwood and B.N. Wolstenholme
Department of Horticultural Science, University of Natal, Private Bag X01, Scottsville, Pietermaritzburg, 3209, RSA

INTRODUCTION

The great distance between South Africa and her export markets has led to research into new means of prolonging the shelf life and improving the quality of the avocado fruit. Both pre-harvest and post-harvest measures have been investigated to further this goal. Previously post-harvest treatments such as controlled atmosphere storage, hypobaric storage and carbon dioxide 'shock' treatments were investigated with varying success. These treatments were briefly reviewed by Allwood and Cutting (1994). The main disadvantage associated with that of controlled atmosphere and hypobaric storage has been the costs involved (Spalding & Reeder, 1975; Apelbaum *et al,* 1977). This led to experimentation with carbon dioxide 'shock' treatment which is less costly (Bower, 1988).

The main focus with pre-harvest treatments has been to improve tree health and thereby attain good quality fruit. Of particular importance has been the nutrient calcium. Fruit with higher calcium levels have shown to have longer shelf lives and ripen with lower levels of physiological and pathological disorders (Tingwa & Young, 1974; Van Rensburg & Engelbrecht, 1986). The problem with calcium has been to get sufficient translocation into the fruit. Leaves tend to have a greater transpiring surface and, initially, sink strength with greater strength than small fruit, resulting in preferential movement to leaves, especially in the critical early stages of fruit growth. Spraying of trees with $Ca(NO_3)_2$ showed little penetration into the fruit and leaves (Veldman, 1983). So far lime application around the trees has proved to be the most effective means of calcium application (Du Plessis & Koen, 1987). Mulching of the trees in the orchard is thought to be a means by which the root environment may be improved leading *inter alia* to a greater uptake of calcium. This in turn would result in an increase in fruit calcium.

The purpose of this paper is to present the results over two seasons of experimentation with carbon dioxide 'shock' treatments, using both CO_2 and N2, and to investigate the effect of mulching of trees in an orchard situation on fruit calcium levels and ripening.

GAS 'SHOCK' TREATMENT

Materials and method

Avocado fruit of Fuerte cultivar were obtained at harvest from Everdon Estates near

Howick in Kwazulu/Natal. For each experiment 15 cartons of count 14 were collected, five cartons were placed into each section of the gas chamber. The gas was then set at the required concentration using N_2 and CO_2 and synthetic air as the oxygen source. In the experiments either CO_2 or N_2 were mixed with synthetic air, using the flow meters. In the 1994 season a second chamber was used enabling both CO_2 and N_2 treatments to be run concurrently. The fruit was pulsed three times every 24 hrs for duration of 48 hrs. After 48 hrs two cartons from each treatment were placed into cold rooms at 3.5°C and 5.5°C, similarly for the controls. Cartons remained in cold storage for four weeks after which fruit were removed from storage and allowed to ripen. The remaining five cartons of fruit were kept as controls. Time taken for the fruit to ripen after storage was then recorded and analyzed. Each chamber (72.5 x 42.5 x 72.5 cm) was made from glass, resembling a fish tank, with a middle dividing partition separating it into two compartments. The chamber was sealed from the top with a PVC lid and o-rings, for each section, mounted into a steel frame ensuring gas tightness. Gas was introduced from the gas cylinders via regulators into flow meters. A separate flow meter was mounted into each lid, enabling different gas concentrations to be set in each section of the chamber. The gas concentrations were monitored at the exhaust using an EGM-1 environmental gas monitor (PP systems, Hertfordshire, UK).

Gas concentrations investigated were: 0.21, 1.05, 2.1, 3.0, and 4.2% O_2 for the nitrogen and synthetic air; and 5, 10, 20, and 25% CO_2 for the CO_2 and synthetic air. Oxygen was maintained at 21% for the CO_2 experiments. In 1994 season three new treatments were added viz. 0.7% O_2, 15% CO_2 and 30% CO_2.

Results and discussion

The first season's results have previously been reported on in a progress report (Allwood & Cutting, 1994). Tables 1 and 2 show the multiple range analyses for all the treatments at 5.5°C and 3.5°C respectively. Figure 1 illustrates the results over 1993 and 1994 for nitrogen treatments at 5.5°C. Results are calculated from the days taken to ripen results of the controls, subtracted from the relevant treatments. Treatments above the zero level outperformed the controls, whilst those below ripened earlier than the controls. Over the two seasons at 5.5°C 0.2%, 4.2% O_2, and 3% O_2 treatments consistently improved shelf life, by 1, 2 and 3.8 days. However these treatments were not significant in 1994. Results over the two seasons show a variation in the effect of the treatments from one season to another at 5.5°C. The 1.05% O_2 treatment decreased shelf life over both seasons. The 2.1% O_2 treatment increased shelf life in 1993 but decreased the shelf life in 1994. In the 1993 season, at 3.5°C 1.05% O_2 and 0.2% O_2 gave the greatest increase in shelf life (Figure 2), with 2 and 1.5 days respectively ($P \leq 0.05$). However in the following season the treatment with the greatest increase in shelf life, at 3.5°C, was that of 3% O_2, with an increase in ripening time of 1.4 days ($P \leq 0.05$). The O.2% O_2 treatment consistently increased shelf life over both seasons although this was not significantly different in 1994. The rest of the 3.5°C treatments of the 1994 season ripened before their respective controls.

Table 1
Multiple range analysis for days to ripen of gas treated avocado fruit stored at 5.5 °C, for the 1994 season. SED = 1.36.

Treatment	*Mean (days to ripen)*	*$P \leq 0.05$*
4.2 % O_2	7.32	a
30 % CO_2	7.21	a
15 % CO_2	6.86	ab
T1 CON 1	6.50	abc
T1 CON 2	6.29	abcd
T2 CON 1	6.19	abcde
0.2 % O_2	6.08	abcdef
10 % CO_2	5.79	bcdef
2.1 % O_2	5.75	bcdef
T2 CON 2	5.74	bcdef
1.05 % O_2	5.64	bcdef
0.7 % O_2	5.60	bcdef
20 % CO_2	5.55	bcdef
25 % CO_2	5.36	cdef
5 % CO_2	5.13	def
3 % O_2	4.92	def
T3 CON 1	4.88	ef
T3 CON 2	4.82	f

Note: common letters denote non-significant differences between treatments with different letters indicating significance

Table 2
Multiple range analysis for days to ripen of gas treated avocado fruit at 3.5 °C, for the 1994 season. SED = 1.3

Treatment	*Mean (days to ripen)*	*$P \leq 0.05$*
30 % CO_2	11.07	a
10 % CO_2	10.11	ab
T1 CON 2	9.68	abc
T2 CON 2	9.36	bcd
T2 CON 1	9.36	bcd
1.05 % O_2	9.05	bcde
4.2 % O_2	8.96	bcde
20 % CO_2	8.89	bcde
T1 CON 1	8.86	bcde
25 % CO_2	8.86	bcde
0.7 % O_2	8.73	bcde
2.1 % O_2	8.68	cde
15 % CO_2	8.39	cde
3 % O_2	8.15	def
5 % CO_2	7.93	efg
0.2 % O_2	6.93	fg
T3 CON 1	6.93	fg
T3 CON 2	6.60	g

Note: common letters denote non-significant differences between treatments with different letters indicating significance

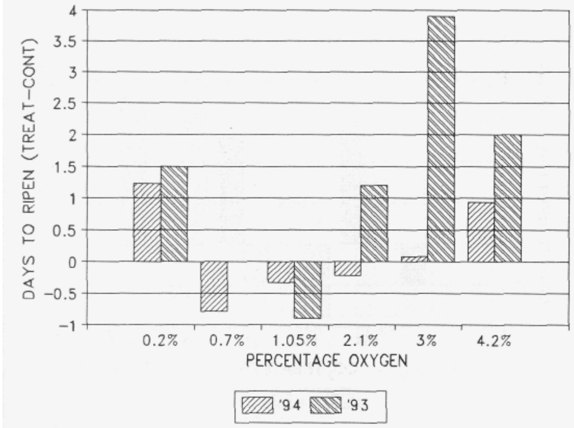

Figure 1
Days to ripen and nitrogen treatment levels for 1993 and 1994 treatments stored at 5.5 °C, relative to the control (= 0).

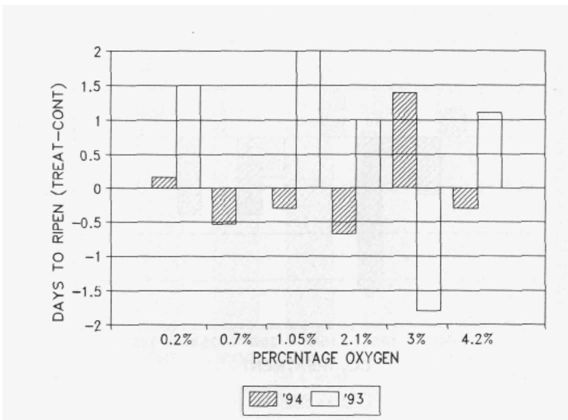

Figure 2
Days to ripen and nitrogen treatment level for 1993 and 1994 treatments stored at 3.5 °C, relative to the control (= 0).

The carbon dioxide treatments at 5.5°C (Figure 3) show a similar trend to the nitrogen treatments, with results varying between seasons. In the 1993 season no treatments improved the shelf life, whilst in the 1994 season all the treatments with the exception of the 10% and 20% CO_2 improved shelf life. However the largest increase was only 0.8 days, barely significant ($P < 0.05$).

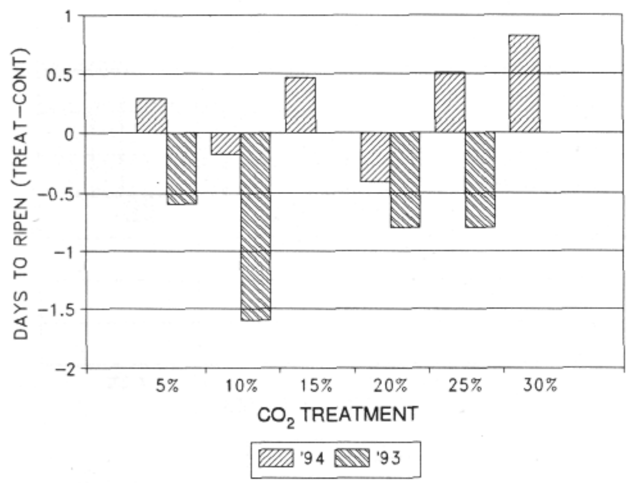

Figure 3
Days to ripen and carbon dioxide treatment level for 1993 and 1994 treatments stored at 5.5 °C, relative to the control (= 0).

At 3.5°C (Figure 4), where in the 1993 season 10% and 20% CO_2 increased the shelf life, only the 15% and 20% CO_2 treatments did not increase shelf life. The largest increase being the 25% CO_2 with 2.1 days increase compared to its control. The 10% CO_2 treatment was the only treatment at this temperature which increased shelf life over the two seasons, although these increases in shelf life are not highly significant. There seems to be very little continuity in both the nitrogen and the carbon dioxide treatments over the two seasons.

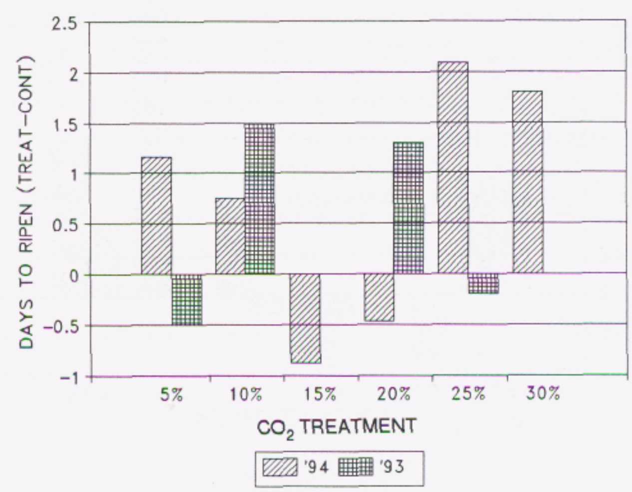

Figure 4
Days to ripen and carbon dioxide treatment level for 1993 and 1994 treatments stored at 3.5 °C, relative to the control (= 0).

MULCH TRIAL

The mulching trial was set up to investigate the effect of different mulch types on fruit quality, particularly the effect on the fruit calcium concentration.

Method and materials

The trial was laid out in a nine year old Fuerte orchard within Everdon Estates near Howick, KwaZulu/Natal. The soil type is a Hutton form with ± 30% clay. A randomised design was used with 4 trees replicated 3 times per treatment. Five mulch treatments were investigated: coarse composted pinebark (supplied by Gromor) with a calcium acetate application of 500 g per tree every two weeks, and without calcium acetate (1.5 m^3 of pinebark was applied per tree inside the tree drip area, around the tree trunk); grass (mainly local veld grass, with a high proportion of Kikuyu); leaf litter allowed to accumulate over the tree life span; and clean being the control, where all litter was removed from under the trees. The control treatment was cleaned three times over the duration of the trial. The mulches were placed under the trees in March 1993 in a single application and were not renewed during the season. The trees received normal orchard care, including irrigation based on a tensiometer reading of -40 KPa; fertilization based on leaf and soil analyses; and basic weed control.

Fifty mature expanded leaves were randomly taken from each treatment for calcium analysis prior to harvest. At harvest fruit were picked from the trees and sent through the packhouse, where count proportions were determined. Ten cartons of count 16 from each mulch treatment were then placed into cold storage at 5.5°C for 4 wks. After cold storage, fruit were allowed to ripen and ripening times determined for each treatment. Samples were taken from the fruit for calcium analysis.

Results

Harvest results are summarised in Figure 5. The largest number of Cartons of large fruit (count 10, 12, 14), came from the pine bark + calcium (PB + Ca) treatment with 45.5 cartons, followed by leaf mulch with 44 cartons, grass with 42.5 cartons, pine bark with 40.5 cartons, and clean or control with only 19 cartons. In the medium fruit size range (counts 16, 18, 20), leaf mulch treatment had 80.5 cartons, grass mulch 57 cartons, PB + Ca 56 cartons, control 54 cartons, and pinebark 32 cartons. For the small fruit (counts 22, 24, 26), the control had the greatest amount viz. 28 cartons; followed by PB + Ca, 11 cartons; and grass and leaf mulch with 9 cartons each. Pine bark mulch alone had no count 22, 24, 26 fruit. For this experiment the factory grade (smaller than count 26) were not monitored. Fruit ripened uniformly with leaf mulch fruit taking slightly longer to ripen (Figure 6). The results on ripening of the mulch treatments are not significantly different ($P \leq 0.05$) as far as length of ripening is concerned.

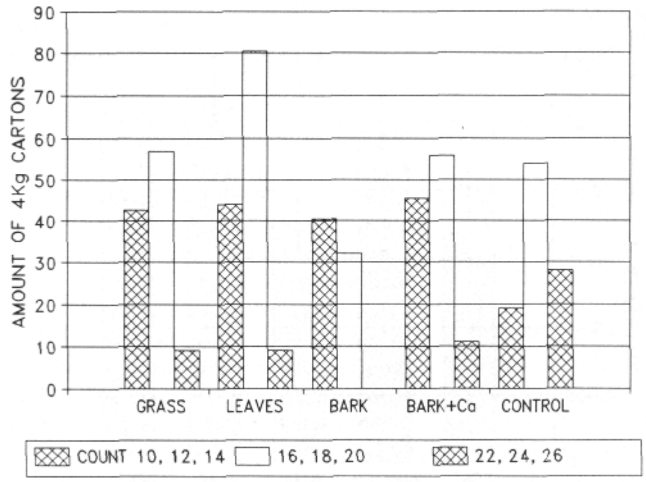

Figure 5
Effect of five mulching treatments on the number of cartons of large (count 10, 12, and 14), medium (count 16, 18, and 20) and small (count 22, 24 and 26) Fuerte, 1994 season.

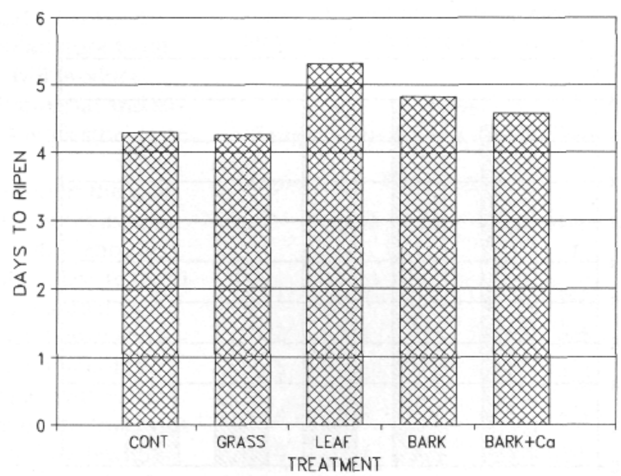

Figure 6
Mean days to ripen for Fuerte fruit harvested from the mulch trials. Results do not differ significantly ($P \leq 0.05$).

Looking at the effect of the mulching on calcium levels in the leaves (Figure 7) and fruit (Figure 8), leaf calcium levels were highest in the bark mulches. Pinebark had 1.85% dry mass (d.m.) of Ca followed by PB + Ca with 1.8% d.m. Ca. The control had 1.68% d.m. Ca, with grass and leaf mulch having 1.58% d.m. and 1.5% d.m. of Ca respectively. In contrast, fruit Ca levels were highest in the leaf mulch (0.0281% d.m. Ca) followed by grass (0.027% d.m. Ca), PB + Ca (0.024% d.m. Ca), control (0.020% d.m. Ca), and pinebark (0.0178% d.m.). Table 3 shows the multiple range analysis of fruit calcium levels. Leaf mulch, grass and PB + Ca are significantly different from the pinebark ($P \leq 0.05$). Leaf and grass mulch are significantly different from the control and pinebark ($P \leq 0.05$).

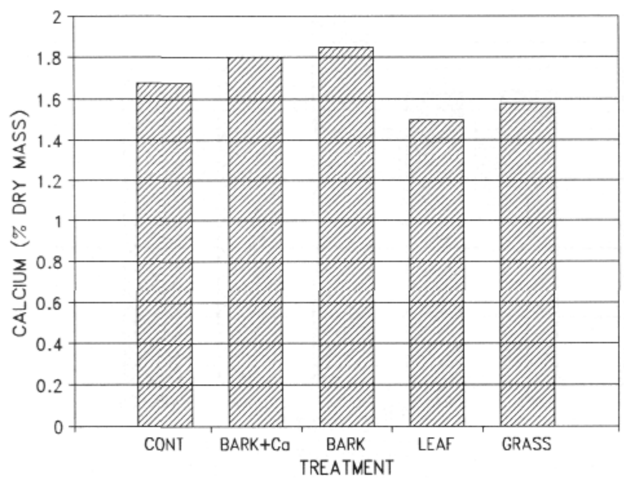

Figure 7
Calcium levels in Fuerte leaves sampled from mulch trials.

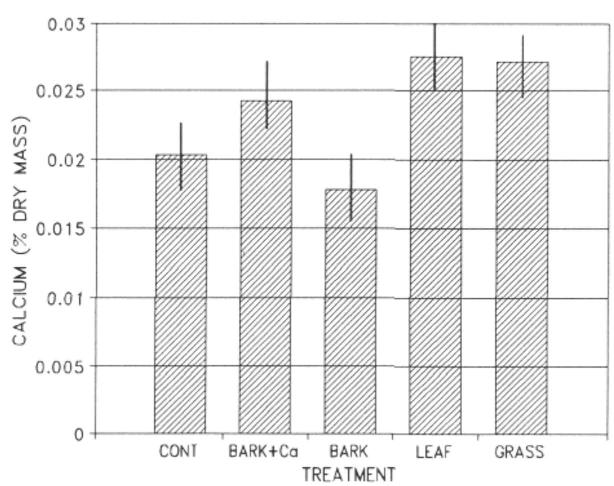

Figure 8
Calcium levels in Fuerte fruit harvested from the mulch trials.
Standard error bar (sed= 0.0053) shows significance at 95 % level.

Table 3
Multiple range analyses for fruit calcium levels in Fuerte avocados showing differences between mulch treatments (SED = 2.12; $P \leq 0.05$)

Treatment	*Count*	*Average calcium level (% dry mass)*	*Homogeneous groups*
Leaf mulch	8	0.02753	a
Grass	8	0.02716	a
Pinebark + Ca	8	0.02425	a b
Control	8	0.02034	b c
Pinebark	8	0.01775	c

Discussion

The results in Figure 5 indicate a trend that mulching treatments increase the fruit size with a greater proportion of larger fruit counts occurring in the mulch treatments. There may be many reasons why this has occurred. Possibly the most important reason has been the improvement in root environment. The avocado tree having a surface feeder root system with a high oxygen requirement, will be able to exploit the mulched area to a greater degree making use of the available nutrients from the mulch decomposition and the better moisture retention and aeration. Further research would be necessary to determine the exact reasons for this fruit size increase. One could expect that the mulching would not change the physiological ripening mechanisms in the fruit which would be the reasons for the small differences in days taken to ripen (Figure 6). The differences in calcium levels of the fruit and leaves (Figures 7 & 8) may be due to many things. The initial composition of the mulches and the carbon to nitrogen ratio will to some extent determine the speed with which the mulches are decomposed or mineralized by detritivores, and therefore the amount of nutrients released to the trees and the timing of that nutrient release. The differences of the mulches on fruit and leaf calcium levels may thus be due to calcium being released at different times, with nutrient release taking place during high fruit or leaf demand periods. Another factor that may influence the effect of the mulch type.

CONCLUSIONS

The results show little promise for gas 'shock' treatment of the avocado fruit in the industry. Results are very variable with little continuity between seasons. 'Shock' treatment alone for increasing shelf life seems to be too variable for commercial viability. However its effect on pathological and physiological disorders still needs to be analyzed. This may still be reason for its use.

Mulching increases fruit size. It is recommended that farmers having fruit size problems should attempt to increase the organic matter under their trees to form mulches. More research is needed to determine the mechanics involved in how mulching actually increases the fruit size, its effect on pathogenicity on the fruit and its economic viability. It is not yet possible to say whether specific types of mulches consistently increase fruit calcium levels.

ACKNOWLEDGEMENTS

The authors would like to thank the South African Avocado Growers' Association for financial support and those at Everdon Estates for the trial site, fruit, and all their assistance.

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