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# PROGRESS REPORT:

# GAS TREATMENT OF 'FUERTE' AVOCADOS TO REDUCE COLD DAMAGE AND INCREASE STORAGE LIFE

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***ABSTRACT***

*Experimentation is under way using various concentrations of nitrogen and synthetic air, and carbon dioxide and synthetic air in order to reduce the fruit's susceptibility to cold and to increase storage life, fruit being stored at* 5.5°C *and* 3.5°C. *Preliminary results show fruit taking on average 7.0 to 10.8 days to ripen depending on gas type and concentration for* 3.5°C, *and 4.7 to 10.6 days for fruit stored at* 5.5°C. *Pathological and physiological disorder incidence was non-significant amongst most treatments although low oxygen levels early in the season resulted in brown cold symptoms after treatment, but before cold storage. Fruit ripened normally after cold storage.*

## INTRODUCTION

In the last few years there has been much ongoing research into finding ways by which producers can get good quality avocado fruit onto the overseas markets. This is particularly relevant for South Africa where the main markets are in the United Kingdom and Europe. Fruit must thus undergo a sea journey of about 24 days, with the time between harvesting and arrival being up to 28 days (Truter & Eksteen, 1987). Many techniques investigated can increase the storage life of the fruit, but most of these are limited by the costs of the treatment. One major need is for fruit to last long enough for shipping and distribution to the consumer, arriving in good condition but ripening before the next consignment arrives.

A brief review of some of the techniques that have been used to extend fruit shelf life and reduce physiological and pathological disorders, will follow.

## CONTROLLED ATMOSPHERE STORAGE

Controlled atmosphere storage (CA) as the name implies is the storage of fruit in specialised containers into which controlled concentrations of gas are introduced. Early research in the 1970's showed that ideal conditions for CA storage of avocados were 2% oxygen and 10% carbon dioxide maintained at 7.2°C, with fruit being stored for up to 60 days (Young *et al*.,1962; Reeder & Hatton,1970; Spalding & Reeder,1972;-Spalding & Reeder,1975). Fruit stored in CA had far less disease incidence than control fruit, with reduced anthracnose decay and chilling injury. Most of these experiments were performed on 'Lula'", 'Booth 8', 'Waldin', and 'Fuchs', which are West Indian type cultivars not grown to any extent in South Africa. More recently experiments have been done by Truter & Eksteen (1987); Bower (1988); Bower *et al.* (1989); and Truter *et al*. (1991). These used 'Fuerte' fruit and obtained similar results with CA treated fruit having reduced physiological and pathological disorders. However, the longer time taken to ripen made the treated fruit more susceptible to post treatment anthracnose damage (Eksteen & Truter, 1985). The main disadvantage of CA relates to the high costs involved for long distance shipping due to the need for sophisticated containers with accurate temperature and gas monitoring equipment.

## HYPOBARIC STORAGE

Fruit are stored at sub-atmospheric pressures in strong chambers connected to vacuum pumps and refrigeration units. The increase in storage life of the fruit is attributed to the reduction of the oxygen partial pressure in the storage chamber and the acceleration of the outward diffusion of ethylene from the fruit (Aharoni, 1984). Apelbaum *et al* (1977) found that avocado fruit stored at 6°C at 60mm Hg after 60 days ripened normally with no skin damage or decay having occurred during storage. The main disadvantage as with CA is the cost of the necessary storage equipment, capable of withstanding the necessary pressures and having the controlling instrumentation.

## CARBON DIOXIDE 'SHOCK' TREATMENT

Research has found that avocados can withstand relatively high levels of $CO_2$ (20 to 30%) providing that $O_2$ is not limiting (Bower, 1988). This has led to another form of fruit treatment, to increase shelf life, where avocados are exposed to high concentrations of $CO_2$ for limited time periods in air-tight containers. Time periods are usually from 1 to 4 days with fruit being treated as close to harvest as possible. Various researchers have investigated this form of treatment but the optimum gas concentrations and duration of treatments have not been finalised (Eksteen & Truter, 1985; Bower, 1988; and Bower, *et al.,* 1989). This 'shock' treatment technique has resulted in significant increases in shelf life as compared to controls (Slabbert & Veldman, 1985). Advantages of this form of treatment, prior to shipping, are the ease with which it can be implemented without the need for sophisticated equipment.

## POLYETHYLENE BAGS

Researchers have investigated the wrapping of fruit either individually or as boxes in polyethylene bags to form modified atmospheres, working on similar principles to that of the $CO_2$ 'shock' treatment. Eksteen & Truter (1985) reported that packaging of fruit in the bags increased the shelf life of the fruit, although a high incidence of anthracnose was also reported. The effect of packaging on chilling injury seems to be contradictory with some experimentation indicating a reduction in injury (Scott & Chaplin, 1978), with other trials showing no difference between treatments and controls (Truter & Eksteen, 1987). Fruit "suffocation" may occur if the bags are retained on the fruit for too long without being opened (Bower, 1988). Disadvantages with this treatment are the need to open bags during treatment to prevent fruit suffocation, and the removal of the bags after treatment, which is labour intensive.

This paper deals with further, preliminary investigations into the $CO_2$ 'shock' treatment, using $CO_2$ and Na.

**MATERIALS AND METHOD**

Avocado fruit of 'Fuerte' cultivar were obtained at harvest from Everdon Estates near Howick in Natal. For each experiment 15 cartons of count 14 were collected, five cartons were placed into each section of the gas chamber. The remainders were kept as controls. The gas was then set at the required concentration using Na and $CO_2$ ,and synthetic air as the oxygen source. In the experiments either $CO_2$ or Na were mixed using the flow meters, with synthetic air. The fruit was then pulsed three times every 24hrs for a duration of 48hrs. After 48hrs 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. Once ripe fruit were rated for black cold, brown cold, lenticold, anthracnose decay, stem end rot, grey pulp, vascular browning, and pulpspot. Rating was done on a scale of 0 to 10 with 0 being clean, no disorder or disease, and 10 being 100% diseased.

Table 1. Least significant differences of days to ripen of gas treated avocado fruit stored at 5.5°C.SED = 0.8079

| TREATMENT | MEAN (DAYS TO RIPEN) | $P \leq 0.05$ | $P \leq 0.01$ |
|---|---|---|---|
| 0.21% $O_2$ | 10.6 | a | a |
| 3.0% $O_2$ | 9.7 | ab | ab |
| 2.1% $O_2$ | 9.5 | abc | abc |
| CONT 2 | 8.3 | bc | abcd |
| CONT 3 | 8.3 | c | abcd |
| 20% $CO_2$ | 7.5 | cd | bcde |
| 1.05% $O_2$ | 7.4 | de | cdef |
| CONT 4 | 7.2 | de | cdefg |
| 10% $CO_2$ | 7.1 | de | cdefg |
| 5% $CO_2$ | 7.0 | de | efg |
| 10% $CO_2$ | 6.7 | def | efg |
| 4.2% $O_2$ | 6.7 | def | efg |
| 25% $CO_2$ | 6.6 | def | efg |
| 5% $CO_2$ | 6.3 | efg | efg |
| CONT 5 | 5.9 | efg | efg |
| CONT 1 | 5.8 | efg | efg |
| 2.1% $O_2$ | 4.9 | fg | fg |
| CONT 6 | 4.7 | g | g |

Note: Common letters denote non-significant differences between treatments with different letters indicating significant differences.

The chamber was made from glass, resembling a fish tank, with a middle dividing partition separating it in two. 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, U.K).

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.

## RESULTS

Table 1 shows the least significant differences of the number of days taken for fruit to ripen that was stored at 5.5°C. At this temperature the treated fruit had a wide range in the number of days taken to ripen from 4.7 to 10.6 days. Treatments 0.21, 3.0, 2.1% $O_2$, Cont 2, and Cont 3 had the longest ripening times when stored at this temperature. These treatments were significantly different from the rest ($P<0.05$). The other treatments stored at 5.5°C show a gradual decrease in ripening times with no highly significant differences. Figure 1 illustrates the differences between the $O_2$ treatment levels. These results are calculated from the days 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 their controls. At 5.5°C the only treatment ripening earlier than its control, for the Na treatments, was the 1.05% $O_2$. All treated fruit in the $CO_2$ treatments ripened before their controls when stored at 5.5°C (fig 2). Fruit stored at 3.5°C (table 2)

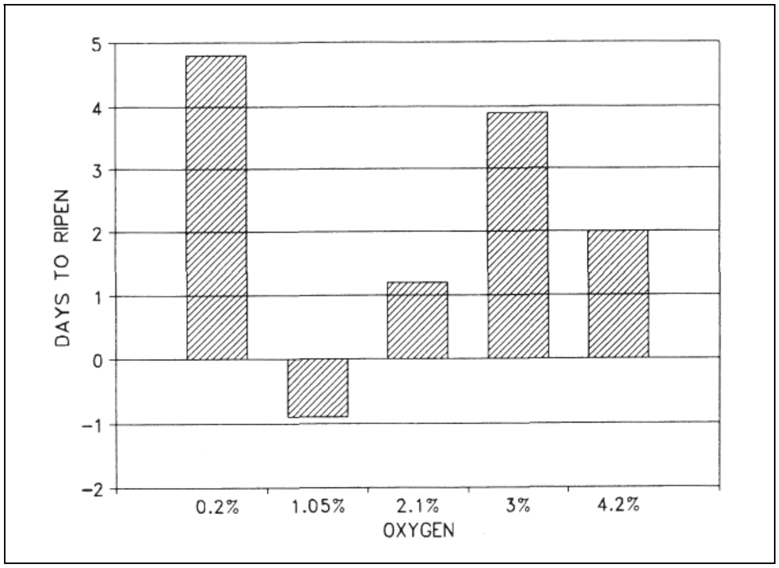


Fig 1. Days to ripen and oxygen treatment levels for nitrogen treatments stored at 5.5°C , relative to control (=0).

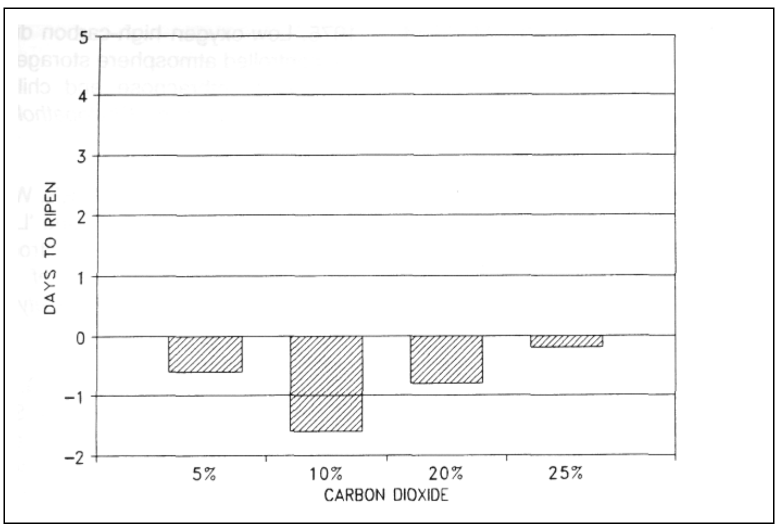


FIG 2. Days to ripen and carbon dioxide treatment level for treatments stored at 5.5°C, relative to the control (=0).

had different ripening times with the longest times taken for treated fruit to ripen being 10.8 days decreasing to 7 days. Treatments 1.05, 0.21% $O_2$ of the Na treatments and 10 and 20% $CO_2$ had the longest ripening times with the rest of the treatments having gradually decreasing ripening times. The differences between treatments are not highly significant although there are significant differences between the 1.05% $O_2$ and the 3.0% $O_2$ treatments ($P \leq 0.01$). In comparing the treatments to the controls for fruit stored at 3.5°C (fig 3 & 4), the 3% $O_2$ was the only $N_2$ treatment that ripened before its control while both 5 and 25% $CO_2$ ripened before their controls.

TABLE 2. Least significant differences of days to ripen of gas treated avocado fruit stored at 3.5°C.

| TREATMENT | MEAN (DAYS TO RIPEN) | $P \leq 0.05$ | $P \leq 0.01$ |
|---|---|---|---|
| 1.05% $O_2$ | 10.8 | a | a |
| 0.21% $O_2$ | 10.3 | a | ab |
| 10% $CO_2$ | 10.3 | a | ab |
| 20% $CO_2$ | 10.1 | ab | ab |
| 2.1% $O_2$ | 9.8 | abc | ab |
| 2.1% $O_2$ | 9.2 | abc | abc |
| 4.2% $O_2$ | 9.1 | abc | abc |
| CONT1 | 8.8 | bcd | abc |
| CONT 2 | 8.8 | bcd | abc |
| CONT 3 | 8.8 | bcd | abc |
| CONT 4 | 8.5 | bcd | abc |
| 25% $CO_2$ | 8.3 | bcd | abc |
| CONT 5 | 8.2 | cd | abc |
| 5% $CO_2$ | 8 | cd | bc |
| CONT 6 | 8 | cd | bc |
| 5% $CO_2$ | 7.1 | d | c |
| 10% $CO_2$ | 7 | d | c |
| 3.0% $O_2$ | 7 | d | c |

SED = 0.8079

Note: Common letters denote non-significant differences between treatments with different letters indicating significant differences.

Due to the lack of both physiological and pathological disorders, no results are given. However one aspect that needs to be mentioned was that all fruit in the first treatment of 0.21% and 3% $O_2$ had severe brown cold symptoms. The lower the $O_2$ the greater the brown cold severity, with fruit having ratings of up to 80% of total fruit surface. These symptoms developed directly after gas treatment before the fruit were placed into cold storage.

**DISCUSSION**

Results shown give no indication of one treatment that uniformly outperformed its control at both 3.5°C and 5.5°C. At 3.5°C the treatment having most potential seems to be 1.05% $O_2$ which, on average took two more days to ripen than the control (mean 10.3± 0.81 days). However at 5.5°C this same treatment ripened earlier than the control. The higher $O_2$ ratios of 2.1% and 4.2% consistently outperformed their controls at both 3.5°C and 5.5°C but giving an increase of only one to two days extended shelf life. At 5.5°C 0.21% and 3.0% Cb gave extended shelf life of on average 4.8 and 3.8 days respectively.

The $CO_2$ treatments in comparison to $N_2$ gave far shorter ripening times with $N_2$ treatments consistently taking longer to ripen, implying a longer storage life. At 5.5°C no $CO_2$ treatment out performed its control, with only 10% and 20% $CO_2$ concentrations having longer ripening periods to their respective controls at 3.5°C.

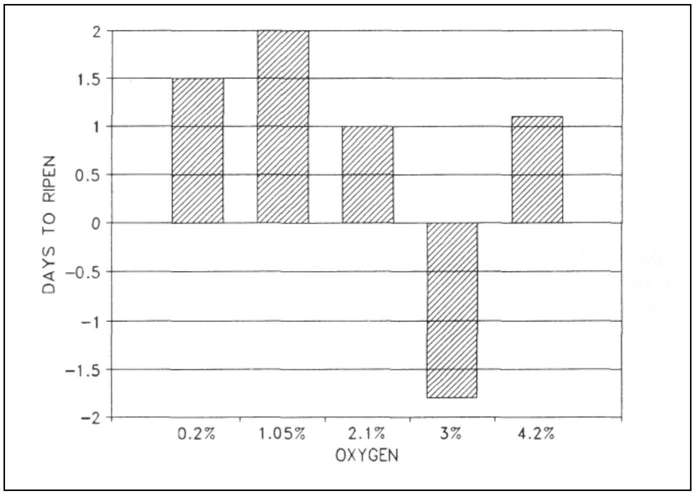


FIG 3. Days to ripen and oxygen treatment level for treatments stored at 3.5°C, relative to the control (=0).

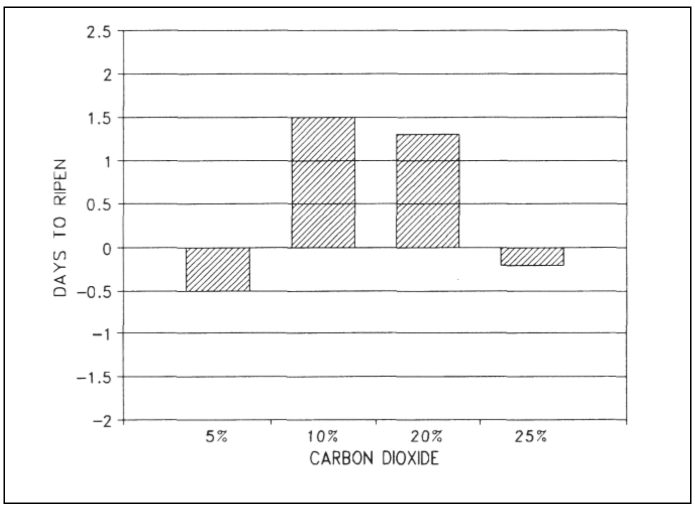


FIG 4. Days to ripen and carbon dioxide treatment level for treatments stored at 3.5°C, relative to the control (=0).

The treatment effect on pathological and physiological disorders was disappointing in that the fruit obtained remained clean, even after treatment and ripening. Both controls and treatments were clean with minor cases of black cold, some grey pulp and anthracnose having occurred. These were so slight that no statistical differences could be found. One disorder of significance was brown cold. This occurred early in the season, but only to the 0.21 % and 3.0% $O_2$ treatments. These symptoms occurred directly after gas treatment, before cold storage. Later treatments of 1.05% and 2.1% 02 showed no brown cold symptoms. This suggests that brown cold is due to an oxygen deficiency.

Earlier fruit seems to be more susceptible to this deficiency. This theory is supported by Spalding and Marousky (1981), where similar symptoms were reported in low oxygen atmospheres of 0.5% O. Fruit with these brown cold symptoms ripened normally, showing no internal discolouration and being perfectly palatable.

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