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Semi-commercial evaluation of SmartFresh™ with South African export avocados in static containers at the Westfalia packhouse during 2002

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ABSTRACT

During the 2000 and 2001 seasons, intensive laboratory testing was done with 1-methyl cyclopropene (1-MCP), an ethylene blocker on avocado fruit. All the major South African cultivars were tested and aspects such as storage potential, respiration rate and fruit quality upon ripening were covered. The results were extremely positive and the manufacturer (Rohm & Haas, USA) has subsequently registered the product in South Africa. During 2002, a tablet formulation of 1-MCP, SmartFresh™, was tested under semi-commercial conditions on 'Fuerte' and 'Hass' at the Westfalia packhouse in Tzaneen. The product was applied in a static reefer container. SmartFresh ™ was found to effectively inhibit the ripening process of 'Hass' and 'Fuerte' under the semi-commercial conditions described above. The inhibition of ripening was more intense in 'Fuerte' than in 'Hass'. Furthermore, the inhibition of ripening was more intense in the smaller count 18 fruit than in the bigger count 10-12 fruit. The increase in storage life was found to be comparable to that attained with control atmosphere storage (CA) when SmartFresh™ was applied at the optimum dosage. The most appropriate packhouse based dosage regime for all sized fruit was determined and commercial application commenced during 2003.

INTRODUCTION

In the past the firmness of export avocados was maintained by reducing the storage temperature during transport. However, temperature control alone will not prevent ripening during a 28 day export period, especially during the late season. Since 1996, controlled atmosphere (CA) became available in South Africa as an additional tool to reduce ripening during storage. Due to the success of this method, virtually all avocados are currently exported under CA. This method certainly improved the chances of landing a hard fruit in Europe and extended the harvesting window. Cold storage and CA both delay the ripening process by slowing down the metabolism of the fruit.

During the 2000 – 2001 seasons, the ARC-ITSC has been evaluating the effectiveness of SmartFresh™, a product containing an ethylene inhibitor, 1-methyl cyclopropene (1-MCP), on avocados (Lemmer *et al.*, 2002). The trials were done in the laboratory using all the major export cultivars and covered aspects such as storage potential, respiration rate and fruit quality upon ripening.

The main conclusions drawn from the initial laboratory based trials were:

- SmartFresh™ slows down the ripening process of avocado under export simulation conditions.
- The ripening retarding effect is more intense on slow metabolizing CV's such as Ryan compared to CV's with a faster metabolism such as Hass.
- SmartFresh™ can be applied over a wide range of concentrations and a dosage effect exists.
- SmartFresh™ can be applied at the temperature the fruit are to be exported at.
- Storage potential of SmartFresh™ treated fruit is comparable to CA fruit.
- SmartFresh™ suppresses respiration rate to a greater extent than CA.
- SmartFresh™ reduces grey pulp under laboratory conditions.
- The storage period is not to be over extended as this may increase the incidence of fungal pathology.

Due to the extremely positive results, the manufacturer (Rohm & Haas, USA) has registered the product on avocados in South Africa.

During 2002, a tablet formulation, SmartFresh™, was tested under semi-commercial conditions on 'Fuerte' and 'Hass' at the Westfalia packhouse in Tzaneen. The product was applied under packhouse conditions in a static reefer container. The research aimed to determine suitable application periods and optimum dosage regimes for 'Fuerte' and 'Hass'avocado fruit.

MATERIAL AND METHODS

Fruit

In the case of 'Fuerte' count 18 (211 – 235 g) and count 10 (366 – 450 g) fruit were used. In the case of 'Hass' count 18 and count 12 (306 – 365 g) fruit were used. Freshly harvested and packed export fruit were sampled for the trials.

Treatments

Taking the previous results into consideration, it was decided to include two SmartFresh™ concentrations (300 ppb and 500 ppb) and to treat the fruit for 16 hours. On packhouse management request, an 8 hour regime was also included in one of the trials. In all cases, the SmartFresh™ treated fruit were compared with untreated control fruit from the same batch.

Smartfresh™ treated fruit were also compared with CA stored fruit (CO_2 = 6% and O_2= 4%). A flow-through CA system (consisting of a 100 L drum connected to gas regulators and a CA control board) was installed in a Westfalia cold room for this purpose.

Treatment application and storage

Two 58m^3 reefer shipping containers were parked at Westfalia packhouse for the duration of the 2002 season. One container was air-tightened and used for treating the fruit while the second was used for cool storage.

A total number of 11 container loads were treated during the season. 'Fuerte' fruit were treated on 18 April, 25 April, 5 June, 23 July, 24 July, 31 July, 2 August. 'Hass' fruit were treated on 5 June, 23 July, 24 July, 2 August, 26 August, 27 August, 28 August, 29 August and 30 August. During the first two trials, export fruit samples (3 boxes per size) were placed in the center of 20 pallets. The rest of the pallets consisted of local market fruit. The aim of the experiment was to establish whether the 1-MCP gas diffused evenly through the container from the point of release at the door. After the application period of 16 hours, the doors and the vents were opened. The pallets were removed and 10 of the pallets were replaced with pallets containing control untreated samples. The pallets were placed in the same order, from the condenser side towards the door of the container. The fruit were stored inside the container with the vents 15% open to simulate the export period to Europe. After a 28 days storage period at the SAAGA prescribed temperature regime, the fruit were ripened at 18°C and evaluated.

During the remaining 9 trials, the treatment container was filled with bulk bins containing local market fruit. Two sets of export fruit samples (three boxes of each count) were placed near the condenser and door, on top of the bulk bins. After treatment, the sample fruit were removed from the pallets and stored in the second empty container.

Evaluation criteria

Individual fruit were comprehensively evaluated as they ripened. This was done by the application of moderate finger pressure to the fruit on a daily basis. Densimeter readings were also taken upon evaluation to ensure that the fruit were cut within similar firmness ranges. Fruit ripening was expressed as the mean number of days until the fruit ripened and a longitudinal ripening profile was composed.

The following criteria were included when evaluating the fruit upon ripening:

- No. of days to ripen
- Bruising
- Black cold damage
- Lenticel damage
- Dusky browning
- Grey pulp
- Pulpspot
- Vascular browning
- Anthracnose
- Stem-end rot.

The physiological and pathological disorders were scored on a scale of 1 – 3 where 1 depicted a mild and 3 a severe disorder.

RESULTS AND DISCUSSION

Figure 1 is a representation of the effect that SmartFresh™ has on the external colour of 'Hass' fruit. This photograph was taken upon

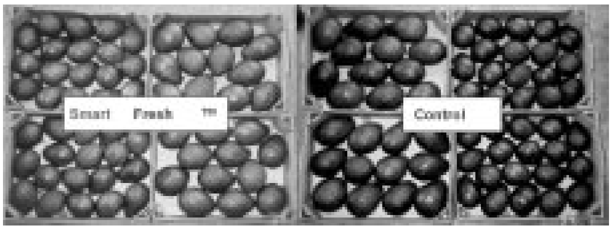

Figure 1. SmartFresh™ slows down the degreening of 'Hass' fruit during cold storage. This photograph was taken directly after storage, during one of the trials where logistical problems caused the control fruit to ripen prematurely.

removal from a 28 day cold storage period in one of the experiments during which certain logistical problems were encountered. The control fruit has started turning black during storage, while the SmartFresh™ treated fruit remained green. This visually exemplifies the ripening inhibition properties of SmartFresh™.

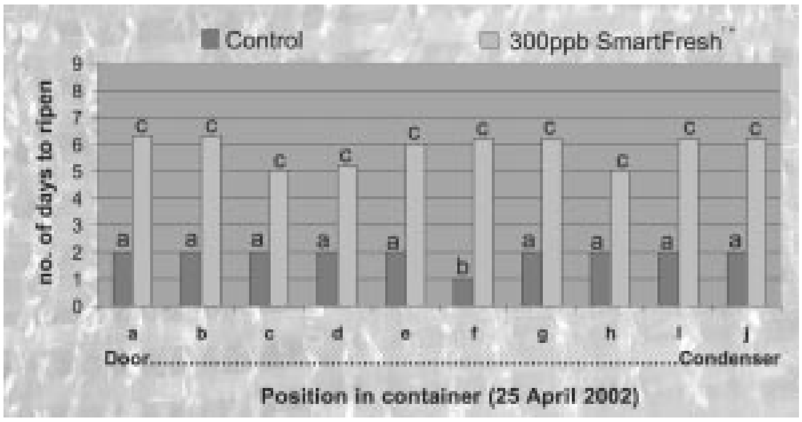

Figure 2. Mean number of days required to ripen count 18 'Fuerte' fruit treated and stored in different pallet positions within the container. The fruit were treated on 25 April with 300 ppb SmartFresh™ for 16 hours before being stored with untreated samples for 28 days at 7°C. Bars marked with the same symbol are not significantly different (Student t-test, P>0.05).

Figure 2 demonstrates the effect of pallet position within the container during the application and storage period on the ripening of 'Fuerte' count 18 fruit. Pallet position did not make a difference. This indicates that Smartfresh™ diffused effectively through the container.

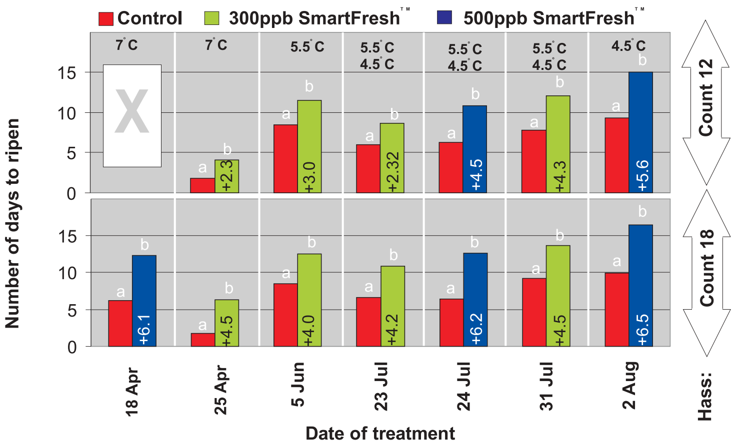

Figure 3. Mean number of days taken to ripen counts 10 and 18 'Fuerte' fruit at 18°C. The fruit were treated on the listed dates inside a 58 m³ refrigerated sea freight container with either 300 or 500 ppb SmartFresh™ for 16 hours, before being stored with untreated samples for 28 days at the indicated export temperatures used at the time. Bars marked with the same symbol are not significantly different. The statistics apply separately for each treatment date and fruit count (Student t-test, P>0.05).

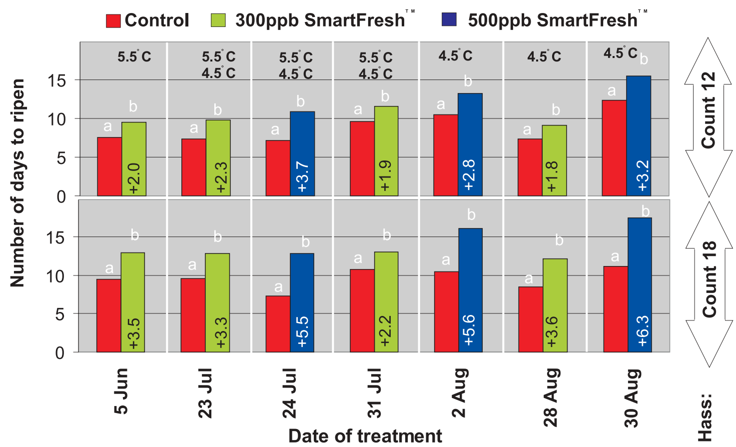

Figure 4. Mean number of days taken to ripen counts 12 and 18 'Hass' fruit at 18°C. The fruit were treated on the listed dates inside a 58 m³ refrigerated sea freight container with either 300 or 500 ppb SmartFresh™ for 16 hours, before being stored with untreated samples for 28 days at the indicated export temperatures used at the time. Bars marked with the same symbol are not significantly different. The statistics apply separately for each treatment date and fruit count (Student t-test, P>0.05).

The **number of days required to ripen 'Fuerte'** fruit during the various trials, is displayed in Figure 3. Treatment with SmartFresh™ led to a significant increase in the average **number of days to ripen**, throughout the season. This was true for the count 18 and count 10 fruit. However, the inhibition of ripening was more pronounced in the smaller count 18 fruit than in the bigger count 10 fruit. When comparing the 300 ppb and 500 ppb treatments, it is clear that the higher concentration of Smartfresh™ more drastically inhibited ripening than the lower concentration. Nevertheless, the effect attained with the 300 ppb treatment was still satisfactory.

During the treatment carried out on 25 April, the packhouse capacity was overloaded. Due to insufficient storage space, the treatment pallets were stored in side halls of the loading zones, with no temperature control. Furthermore, only one forklift was available which had to be shared with the packhouse and oil-factory. For this reason, the palletelised fruit stood outside in the sun for several hours. Regardless of these sub-optimal conditions, the 300 ppb treatment was still able to retain storage potential. This is a very promising observation, indicating that SmartFresh™ will have a buffering effect against temperature related hick-ups in the cold chain.

The **number of days until ripe** recorded for **'Hass'** fruit is shown in Figure 4. A trend similar to 'Fuerte' was observed. However, the Hass fruit, especially the bigger count 12 fruit, reacted less favourably than 'Fuerte' to the SmartFresh™ treatment. This might be contributed to the higher metablic rate of 'Hass' fruit. The gen-

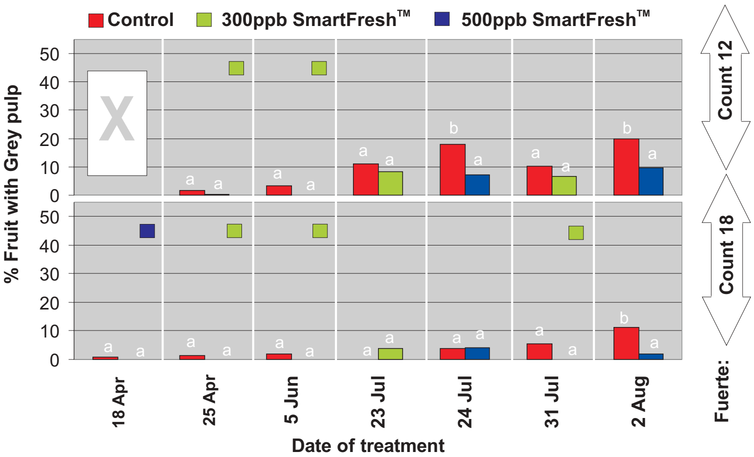

Figure 5. Percentage counts 10 and 18 'Fuerte' fruit with grey pulp as recorded when the fruit ripened. The fruit were treated on the listed dates inside a 58 m³ refrigerated sea freight container with either 300 or 500 ppb SmartFresh™ for 16 hours, before being stored with untreated samples for 28 days at the SAAGA export temperatures used at the time. Bars marked with the same symbol are not significantly different. The statistics apply separately for each treatment date and fruit count (χ^2-test, P<0.95).

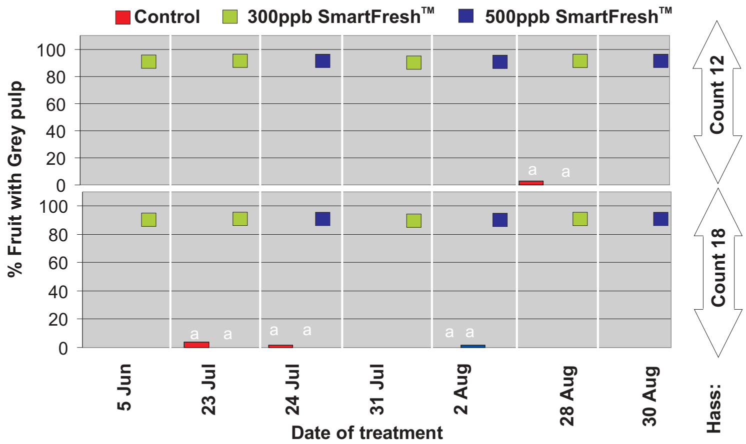

Figure 6. Percentage counts 12 and 18 'Hass' fruit with grey pulp as recorded when the fruit ripened. The fruit were treated on the listed dates inside a 58 m³ refrigerated sea freight container with either 300 or 500 ppb SmartFresh™ for 16 hours, before being stored with untreated samples for 28 days at the SAAGA export temperatures used at the time. Bars marked with the same symbol are not significantly different. The statistics apply separately for each treatment date and fruit count (χ^2-test, P<0.95).

eral effect was nonetheless acceptable and, as will be shown later, very similar to that attained with CA.

The percentage **'Fuerte'** fruit with **grey pulp** is portrayed in Figure 5. The untreated fruit showed an increasing prevalence as the season progressed and this trend started earlier and to a greater extend in the bigger count 10 fruit. It is promising to note that the Smartfresh™ treatments led to a significant decrease in the grey pulp incidence of, especially, the count 10 fruit. The reduction was more prominent and consistent in the higher dosage treatments (500 ppb) of 24 July and 2 August.

The incidence of grey pulp in **'Hass'** fruit is portrayed in Figure 6. The prevalence of the disorder was too low to draw any conclusions.

The incidence of **anthracnose** in **'Fuerte'** is represented in Figure 7. As the season progressed, the incidence of the infection increased. It is therefore promising to note that only one SmartFresh™ treatment (count 10; treated on 31 July) showed a significantly higher incidence of anthracnose. We expected the lengthening of the storage period to cause more anthracnose infections.

A similar trend was noticed in **'Hass'** (Figure 8). Only one SmartFresh™ treatment showed a significant increase in anthracnose infection (count18; treated on 30 August). This treatment was done at the higher dosage (500 ppb) and the ripening period was considerably longer in this specific case. The intensity of the infection was also influenced. With the control, all 16% of infected fruit scored 1. With the SmartFresh™ treatment, 16% of the fruit obtained a rating of 1, while

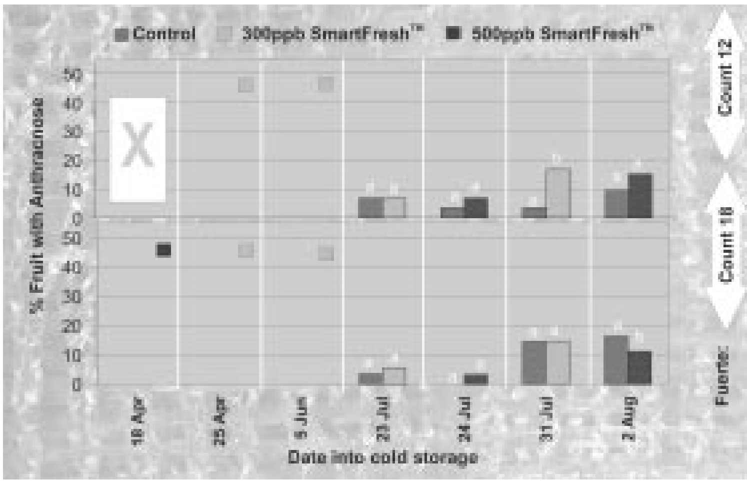

Figure 7. Percentage counts 10 and 18 'Fuerte' fruit with anthracnose, as recorded when the fruit ripened. The fruit were treated on the listed dates inside a 58 m^3 refrigerated sea freight container with either 300 or 500 ppb SmartFresh™ for 16 hours, before being stored with untreated samples for 28 days at the SAAGA export temperatures used at the time. Bars marked with the same symbol are not significantly different. The statistics apply separately for each treatment date and fruit count (χ^2-test, P<0.95).

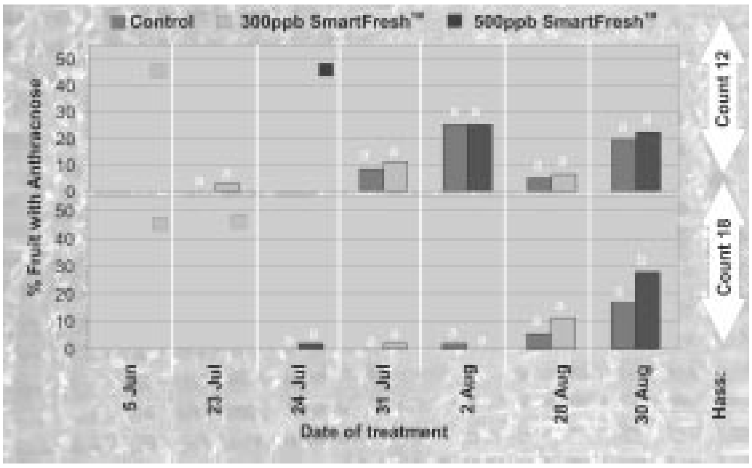

Figure 8. Percentage counts 12 and 18 'Hass' fruit with anthracnose, as recorded when the fruit ripened. The fruit were treated on the listed dates inside a 58 m^3 refrigerated sea freight container with either 300 or 500 ppb SmartFresh™ for 16 hours, before being stored with untreated samples for 28 days at the SAAGA export temperatures used at the time. Bars marked with the same symbol are not significantly different. The statistics apply separately for each treatment date and fruit count (χ^2-test, P<0.95).

7.4% scored 2 and 3.7% scored 3. Care must therefore be taken not to over extend the shelflife by using too high a dosage. This was also noticed in the laboratory trials conducted during the previous 2 seasons (Lemmer *et al.*, 2002).

The percentage of '**Fuerte**' fruit with **stem-end rot** is displayed in Figure 9. The control fruit did not show a significant increase in infection towards the end of the season. However, the Smartfresh™ treatments did. This increase was earlier and more prominent in the count 10 fruit and was again caused by the lengthening of the storage period.

With '**Hass**', the early season SmartFresh™ treatment conducted on 5 June, led to a significant increase in **stem-end rot** (Figure 10). In this regard it must be mentioned that it is common to find a high incidence of **stem-end rot** infection at the beginning of the harvest window, when the fruit are still relatively immature. This is exacerbated by further lengthening of the storage period. However, the severity of the infection was not influenced.

The highest incidence of in stem-end rot in 'Hass' was recorded during the late season (2 and 30 August) in count 12 fruit. These treatments were both done at the higher 500 ppb regime and at first glance may be ascribed to the lengthening of the storage period. However, these two trials also showed the highest incidence of **lenticel damage** (Figure 11) and **bruising** (Figure 12). The pre-harvest quality of the fruit was obviously poor.

In Table 1, SmartFresh™ is compared with CA. Both methods inhibited ripening to a similar degree in count 12 Hass fruit during both the early (Table 1a) and the late (Table 1b) season. During the early season, no

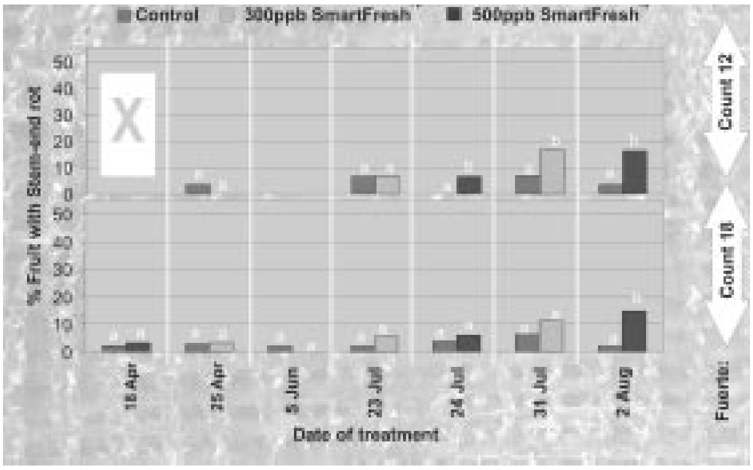

Figure 9. Percentage counts 10 and 18 'Fuerte' fruit with stem-end rot, as recorded when the fruit ripened. The fruit were treated on the listed dates inside a 58 m^3 refrigerated sea freight container with either 300 or 500 ppb SmartFresh™ for 16 hours, before being stored with untreated samples for 28 days at the SAAGA export temperatures used at the time. Bars marked with the same symbol are not significantly different. The statistics apply separately for each treatment date and count fruit (χ^2-test, $P<0.95$).

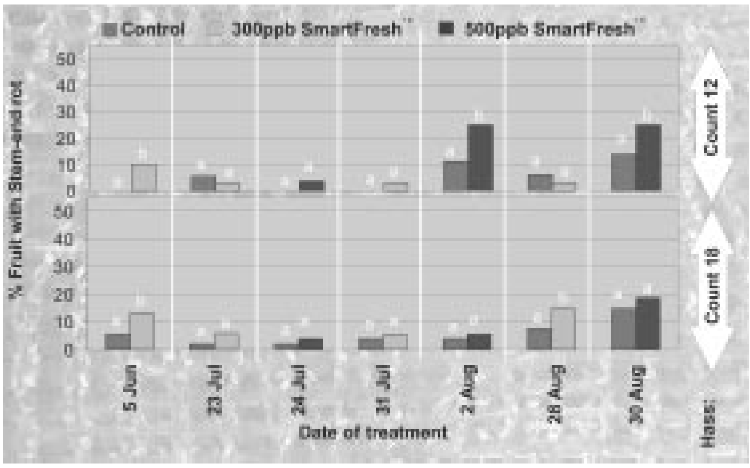

Figure 10. Percentage counts 12 and 18 'Hass' fruit with stem-end rot, as recorded when the fruit ripened. The fruit were treated on the listed dates inside a 58 m^3 refrigerated sea freight container with either 300 or 500 ppb SmartFresh™ for 16 hours, before being stored with untreated samples for 28 days at the SAAGA export temperatures used at the time. Bars marked with the same symbol are not significantly different. The statistics apply separately for each treatment date and count fruit (χ^2-test, $P<0.95$).

anthracnose occurred in any of the treatments. However, during the late season both Smartfresh™ and CA caused significant increases in the incidence of anthracnose infection. Both treatments also caused an increase in the incidence of stem-end-rot during the early season. Although the interpretation of the late season data was confounded by discrepancies between the cold room and container data, a similar trend seemed to exist. As mentioned repeatedly, the observed increase in pathological disorders can be contributed to the lengthening of the shelf-life period. This gives the infections more time to develop under favourable conditions.

In Figure 13, the 8 hour exposure period is compared to the 16 hour treatment period. Three SmartFresh™ dosage regimes were used, namely 300 ppb, 400 ppb and 500 ppb. From the graph it is clear that the 8 hour regime was less effective than the 16 hour regime. In case of count 12 fruit, no significant increase was obtained at both the 300 ppb and 400 ppb concentrations when treated for 8 hours. Only the 500 ppb treatment gave a significant increase in shelf life when treated for 8 hours. In case of the smaller count 18 fruit, both the 400 ppb and 500 ppb treatments were effective when applied for 8 hours.

The above results infer that different concentrations of SmartFfresh™ is required for small and large fruit, when treating the fruit for 8 hours. However, the relatively small volumes of count 10 – 12 fruit packed makes this impractical. Furthermore, the increased dosage needed for the 8 hour regime will have unnecessary cost implications. As the 300 ppb/16 hour was effective for both cultivars as well as for

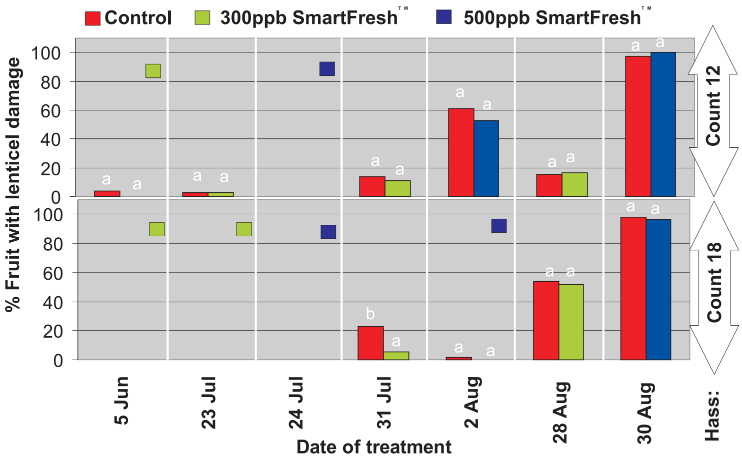

Figure 11. The percentage counts 12 and 18 'Hass' with lenticel damage, as recorded upon removal from cold storage. The fruit were treated on the listed dates inside a 58 m³ refrigerated sea freight container with either 300 or 500 ppb SmartFresh™ for 16 hours, before being stored with untreated samples for 28 days at the SAAGA export temperatures used at the time. Bars marked with the same symbol are not significantly different. The statistics apply separately for each treatment date and count fruit (χ^2-test, P<0.95).

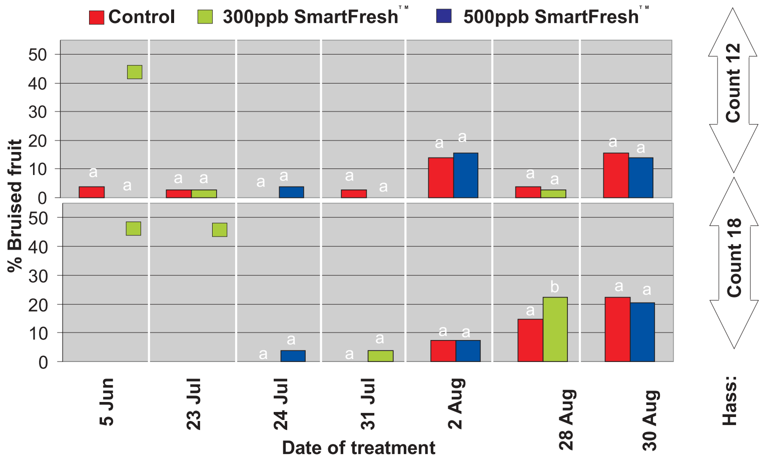

Figure 12. Percentage bruised counts 10 and 18 'Hass' fruit, as recorded when the fruit ripened. The fruit were treated on the listed dates inside a 58 m³ refrigerated sea freight container with either 300 or 500 ppb SmartFresh™ for 16 hours, before being stored with untreated samples for 28 days at the SAAGA export temperatures used at the time. Bars marked with the same symbol are not significantly different. The statistics apply separately for each treatment date and count fruit (χ^2-test, P<0.95).

small and large counts, this is obviously the better recommendation.

Ad Hoc laboratory trials conducted during 2002

In addition to the semi-commercial trials described above, two laboratory scaled trials were conducted during 2002. The trials were conducted at Westfalia Estates using the equipment and procedures described by Lemmer *et al.* (2002).

A question often asked is: "Will it be possible to treat avocado fruit in a cool truck while in transit to Cape Town harbour?" This implicates a longer exposure periods than the above 16 hour recommendation. To answer this question, the fruit were treated with 300 ppb for respectively 16, 24 or 36 hours. The results are shown in Table 2. There was no difference between the treatments in terms of the number of days to ripen (Table 2) or fruit quality (data not shown). This indicates that the lengthened treatment period had no negative effect.

The second experiment aimed to determine what effect a delay between packing and treating has on storage potential of the fruit. To do this, 'Hass' fruit were treated with 300 ppb SmartFresh™ for 8 hours directly after harvest as well as after 3 and 7 days. The results are shown in Table 3. When applied 3 days after harvest, the SmartFresh™ treatment was as effective as when applied directly after harvest. When applied 7 days after harvest, the treatment was slightly less effective and it led to increased pathological disorders (data not shown) which is undesirable.

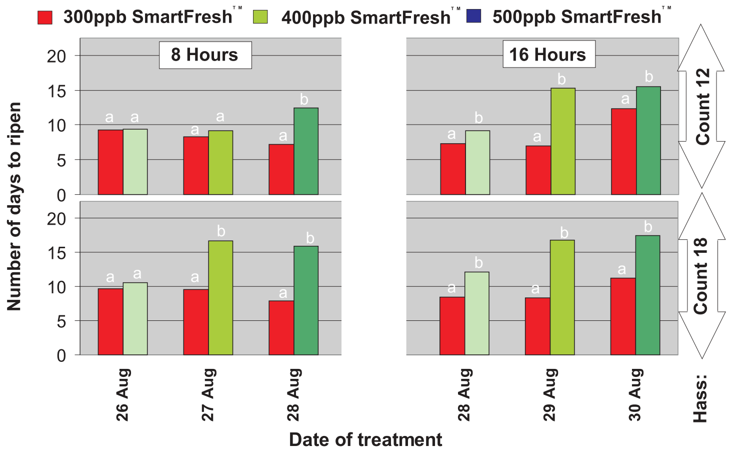

Figure 13. Mean number of days taken to ripen counts 12 and 18 'Hass' fruit at 18°C. The fruit were treated inside a container with either 300, 400 or 500 ppb SmartFresh™ for 8 or 16 hours, before being stored with untreated samples for 28 days at the recommended export temperature. Bars marked with the same symbol are not significantly different. The statistics apply separately for each treatment date and fruit count (Student t-test, P>0.05).

SUMMARY AND RECOMMENDATIONS

Prevention of soft landings

- **SmartFresh ™** effectively inhibited the ripening process of '**Hass**' and '**Fuerte**' under bigger volume **semi-commercial conditions**.
- The increase in storage life is comparable to CA when **Smartfresh™** is applied at optimum dosage.
- The inhibition of ripening is more intense in '**Fuerte**' compared to '**Hass**'.
- The inhibition of ripening is more intense in the smaller **Count 18** fruit compared to bigger **Count 10-12** fruit.

Physiological disorders

- Smartfresh™ reduced the incidence of **grey pulp** during certain trials.
- The reduction was greater at the 500 ppb concentration than at the 300 ppb concentration.

a).

Early season	Container storage @ 5.5°C 5/6/02 - 2/7/02			Container storage @ 5.5°C 5/6/02 - 2/7/02	
	Control	S.Fresh™ 300ppb	CA	Control	S.Fresh™ 300ppb
Days to ripen	**7.00a**	**11.50b**	**10.90b**	**9.50a***	**13.00b***
Anthracnose %	0.00	0.00	0.00	0.00	0.00
Stem-end rot %	0.00a	5.5b	8.30b	5.60a	13.00b

b).

Late season	Coldroom storage @ 4.5°C 2/8/02 - 30/8/02			Container storage @ 4.5°C 2/8/02 - 30/8/02	
	Control	S.Fresh™ 500ppb	CA	Control	S.Fresh™ 500ppb
Days to ripen	**9.40a**	**12.80b**	**12.10b**	**10.40a***	**13.20b***
Anthracnose %	5.70a	11.00b	16.00b	25.00a	25.00a
Stem-end rot %	11.4a	8.30a	29.00b	11.00a	25.00b

Table 1. Comparison of the effect of CA and SmartFresh™ on count 12 'Hass' fruit in terms of the number of days to ripen and the incidence of pathological disorders recorded during the early (a) and late (b) season.

	300ppb *SmartFresh*		
	Treated directly after harvest		
Control	16 hours	24 hours	36 hours
8.222 a	12.556 b	12.560 b	11.589 b

Table 2. Number of days to ripen count 18 'Hass' fruit treated with 300ppb SmartFresh™ inside a 100l plastic container for 16, 24 or 36 hours, before being stored with untreated samples for 28 days at the recommended export temperatures, inside the 58m³ sea freight container. Values marked with the same symbol are not significantly different (Student t-test, P>0.05).

	300ppb *SmartFresh* 16 hours		
	Treated	Treated after a period of:	
Control	directly	3 days	7 days
8.222 a	12.556 b	12.668 c	10.102 b

Table 3. The effect that a postharvest delay before the SmartFresh™ application has on the number of days to ripen 'Hass' count 18 fruit. The fruit were treated inside with 300ppb SmartFresh™ inside a 100 l plastic container for 16 hours, either directly after harvest or after a 3 or 7 day delay, before being stored with untreated samples for 28 days at the recommended export temperature, inside a 58m³ sea freight container. Values marked with the same symbol are not significantly different (Student t-test, P>0.05).

- The reduction was most noticeable in bigger sized fruit, especially at the end of the season when the incidence of grey pulp was at its highest.

Pathological disorders

- In both Smartfresh™ treated and CA stored fruit the lengthening in days to ripen **does not** influence **anthracnose** infection incidence in the **early season**.
- During the **late season, increased anthracnose** infection incidence sometimes occurred in both Smartfresh™ treated and CA stored fruit.
- Lengthening of ripening period sometimes led to an **increase** incidence of **stem-end rot** in both CA and Smartfresh™ treated fruit. This was more prominent at the end of the season.
- The increased incidence of pathological disorders associated with the lengthened shelf life is exacerbated by the pre-harvest quality of the fruit.

Dosage and treatment period

- At this stage, it is recommended that packhouses apply SmartFresh ™ to 'Fuerte' and Hass fruit at a concentration of **300 ppb for a period of 16 hours**.
- The Smartfresh™ is most effective when applied **within 3 days after harvest**.

LITERATURE CITED

LEMMER, D., KRUGER, F.J., MALUMANE, T.R. & NXUDU, Y. 2002. 1-Methyl cyclopropene: an alternative for controlled atmosphere storage of South African export avocados. *Journal of the South African Avocado Growers' Association*, 25: 28-39.