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RESOLVING LONG DISTANCE SHIPPING DISORDERS IN 'HASS' AVOCADOS

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SUMMARY

A number of disorders are prevalent in avocados when shipped long distances. There may be external chilling injury, but usually more seriously, is internal collapse manifested as some form of mesocarp discoloration, and pathological decay. In order to decrease postharvest stress, and extend shelf life, the concept of minimizing water loss and decreasing the rate of carbohydrate reserve usage, was studied. The use of wax fruit coatings was compared to untreated controls and packaging fruits in micro-perforated polypropylene bags. Storage temperatures of 2°C, 5.5°C and 8°C were investigated. It was found that low (2°C) storage for 30 days resulted in internally sound fruit, and that by minimizing fruit mass loss during storage, the potential for chilling injury could be decreased. A threshold value of mass loss relating to external damage at 2°C is suggested. The lower temperature resulted in lower CO_2 exchange after discharge of fruit, and such fruit also took longer to soften, extending the shelf life. The most successful treatment was packing the fruit in micro-perforated polypropylene bags. It is suggested that this technology could be extended to cartons and even pallets. The type of fruit cooling also appeared to be important, and it is suggested that hydrocooling be considered. Further work is being conducted to investigate the effects of fruit origin and maturity on quality, using the suggested technologies which minimizes fruit water loss and allows for lower shipping temperatures and consequently improved quality.

Key words: Avocado, 'Hass', water loss control, long distance low temperature shipping, disorders.

INTRODUCTION

A number of countries have export as a primary objective in their avocado industries. This often requires long transport and distribution times. Further, in some cases, long distance shipping across countries in addition to the export process is required. As a result, there is a need to maintain fruit quality for extended periods.

There are a number of quality issues which need to be considered when fruit is kept for long periods after harvest. The ripening pattern is important in that fruit needs to remain hard until entering the final distribution chain, otherwise risk becomes excessive and fruit will be discounted by buyers. Fruit should therefore be hard on arrival after shipping. However, fruit still needs to soften normally after ethylene treatment in a ripening programme, or naturally if left to ripen, which should be long enough for distribution and sale, but also not be excessively long, as experience has shown that unacceptably high levels of decay are likely. Externally, there should also be no visible chilling injury resulting in cell collapse.

From an internal quality perspective, the mesocarp should show no physiological abnormalities such as pulpspot or, as often found, grey pulp or mesocarp discoloration.

Apart from the physiological disorders linked to shipping, an important component of quality is the degree of pathological disorders such as anthracnose found in a consignment. Although a preharvest infection which remains quiescent until fruit starts softening, the initial infection level, period of shipping, conditions pertaining during shipping, rate of softening, and fruit physiological characteristics may all play a role in the severity of postharvest disease.

In order to minimize quality defects and at the same time maximize potential shipping times, it has been assumed that the majority of defects are linked to the stress imposed on the fruit during shipping. In the case of external chilling injury, as well as internal disorders such as greypulp, oxidative stress and cell membrane disruption due to the imposed stress (Wismer, 2003) probably preceded visible damage, resulting in the browning enzyme polyphenol oxidase (PPO) reacting with the normally separate phenolic substrate, thus causing a dark coloration or general tissue collapse (Vaughn & Duke, 1984).

When fruit is harvested, it is removed from its source of water and energy supply in the form of carbohydrates (King & O'Donoghue, 1995). It has been suggested that stress induced by water loss may initiate or enhance the softening process (Bower & Cutting, 1988), which in turn is energy intensive, reducing carbohydrate stores. If any factor or combination thereof, inducing stress, exceeds a threshold level, oxidative stress (Toivonen, 2003) cell damage can be expected, resulting in the disorders often encountered. A reduction in water loss and respiration rate (thereby reducing the rate of carbohydrate usage) may therefore result in extended shelf life.

The objective of the work conducted and reported on in this paper, was to investigate techniques (and in particular water loss control) to reduce as far as possible, the rate of postharvest stress development, and thereby prolong the acceptable shelf life of fruit under long distance shipping. The experimental work outlined was conducted over a number of seasons, and thus eliminates the possibility of seasonal variation.

MATERIALS AND METHODS

Fruits were sourced from KwaZulu–Natal, South Africa during season 1, and from this and a source in Limpopo province, South Africa during season 2. All fruit were of count 16 to eliminate the effects of fruit size. Immediately after harvest, fruit were transported to the laboratory, and treated for storage within one day of harvest, with the exception of fruit from Limpopo which took longer. The conditions pertaining temperature during the transport period were noted.

Season 1:

The following treatments were applied:

Control:	No additional postharvest treatment
Wax 1:	Wax from supplier 1
Wax 2:	wax from supplier 2
Poly bag:	Polypropylene bag with 9µm perforations and anti-mist coating
Poly scrub bag:	polyethylene bag with ethylene absorbing coating

Fruits were massed before and after storage so as to calculate mass loss during storage, and fruit then stored for 30 days at 2°C, 5.5°C or 8°C.

At the end of the storage period, packaged fruits were removed, and allowed, together with the unpackaged fruits, to ripen at 20°C.

On the day of removal, from storage, and once all fruits had equilibrated to 20°C, an estimate of respiratory activity was made by measuring CO_2 evolution. Fruit were placed in glass jars and sealed for 10 minutes. Thereafter, CO_2 concentration in the jar was measured using a PP Systems infrared gas analyzer. Net CO_2 exchange was estimated from the change in CO_2 concentration in the jar over time, after taking into account residual headspace. Results were expressed per kg fruit.

Fruits were allowed to soften, and the degree of softness estimated with a densimeter reading on a scale of 0 to 100 where 100 is hard and 0 soft. A fruit with a reading of approximately 55 was deemed eating ripe.

Overall external and internal quality evaluations were conducted, to estimate chilling injury and mesocarp discoloration.

Season 2:

Fruit was sourced from the same KwaZulu-Natal supplier as season 1, and was of the same count. Fruit was also obtained from a packhouse in Limpopo province. The latter fruit was subjected to fluctuating temperatures during the transport period, which could have resulted in an acclimation to later lower temperatures. The maximum temperature fluctuated between 23.5°C and 16°C, while the minimum temperature was between 14.5°C and 8.5°C. Fruit were reduced to storage temperature on the 4th day after harvest.

Postharvest treatments were as follows:

Control:	No additional postharvest treatment
Wax:	Standard wax as used by both packhouses where fruit was sourced
Poly bag:	Polypropylene bag with 9µm perforations and anti-mist coating

Fruit was stored for 30 days at 2°C and 5.5°C, but sufficient was packed to allow for evaluation at 10, 20, and 30 days of storage. After 30 days of storage, fruit was evaluated for external defects and then allowed to ripen before evaluating internal quality. In addition, fruit mass was determined at start and at each sampling stage. Fruit was removed from the polypropylene bags during ripening.

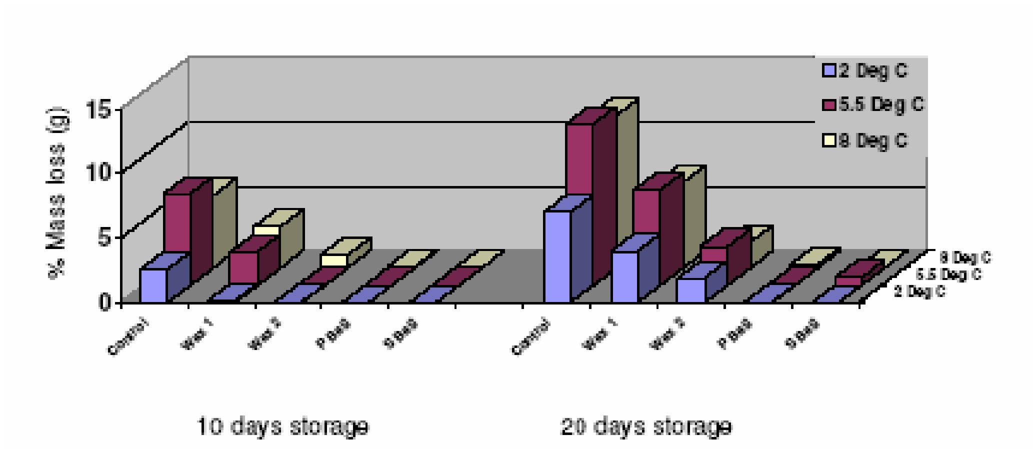

Figure 1. Fruit mass loss as influenced by time of storage, temperature of storage and postharvest treatment.

RESULTS AND DISCUSSION

Fruit mass loss:

The change in fruit mass during storage as influenced by the packaging or postharvest treatment in season 1, is shown in Figure 1. It is evident that the least mass (assumed to be primarily water) loss occurred at a shipping temperature of 2°C. Within all the tested temperatures, the control fruit had the highest mass loss. Waxed fruit had a lower mass loss, but the type of wax also seemed important, as the fruit of wax 2 lost less mass than that of wax 1. This is similar to results previously obtained by Bower *et al.* (2003), who also found that the wax formulation was critical to effectivity, and that those in use in the industry differed considerably. However, of particular note was that the two treatments packaged in bags, lost significantly less mass than any other treatment. The most effective at mass loss control was the polyethylene scrubber bag. However, this may be deleterious, in that postharvest decay is more likely (Eksteen & Truter, 1985; Dixon *et al.* 2003). The micro-perforated bags prevented any accumulation of free water, and also allowed for more gaseous exchange unlike the polyethylene bag and possibly the wax formulations (Bower *et al.* (2003) thus preventing the possibility of high CO_2 build-up which may also result in fruit damage (Bower & Van Lelyveld, 1985; Hagenmaier & Baker, 1993), and therefore appeared to be the best option for postharvest mass (water) control. It was also notable that at least half of the total mass loss occurred during the first 10 days of storage, which therefore included the initial cooling period, when warm fruit is subjected to cold air, and thus looses water (Wills *et al.* 1998). This clearly raises the question of cooling technique. It is suggested that considerably less water loss will occur if hydrocooling is used instead of static or forced air cooling. Further work done on the Limpopo (Figure 2) and KZN (Figure 3) fruit in season 2 showed very similar results. Again, the highest water loss occurred in the control fruits, and significantly less in the packaged fruit. Waxed fruit was intermediate in terms of mass loss. Fruit from KZN (Figure 3) was very similar to that from Limpopo, with once again a considerable portion of the total mass loss occurring early in the shipping period. Fruit at 5.5°C (data not shown) had the same tendency as that at 2°C. While untreated and waxed fruit continued to loose mass throughout the storage period, the packaged fruit very quickly reached equilibrium, with high water vapour content in the package, and little further mass loss thereafter.

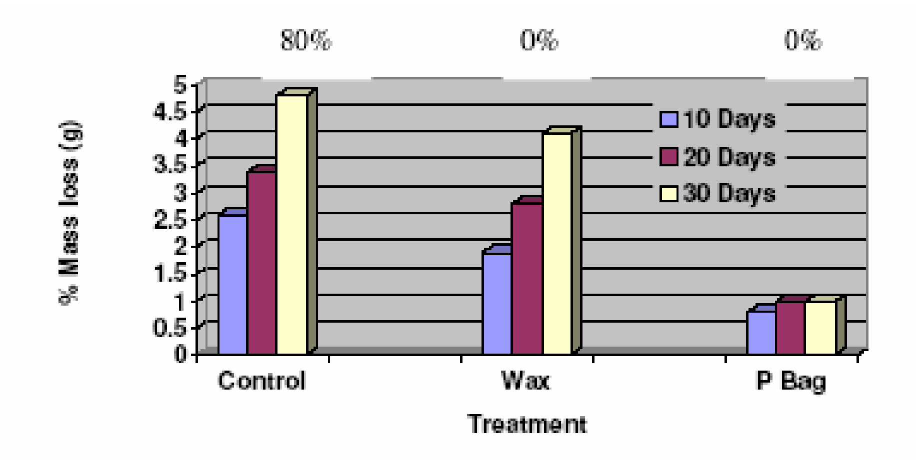

Figure 2. Effect of treatment on fruit mass loss and external chilling injury (indicated as %) after storage at 2°C for 10, 20 and 30 days (Limpopo fruit).

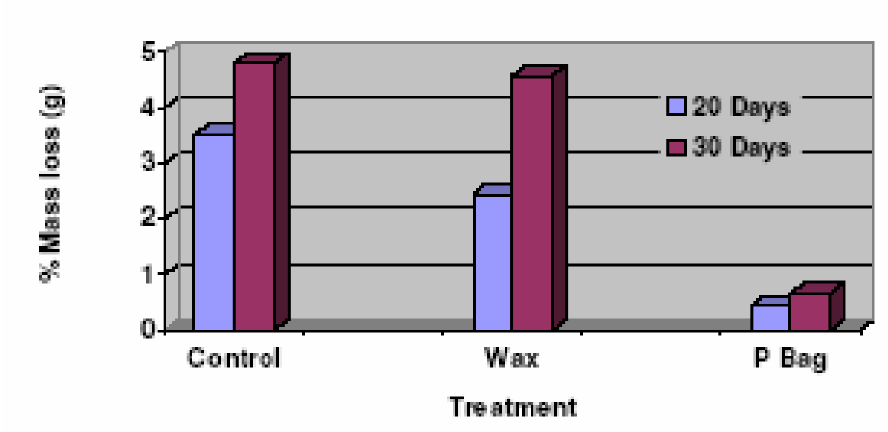

Figure 3. Effect of treatment on fruit mass loss after storage at 2°C for 20 and 30 days. There was no external chilling damage (KZN fruit).

Fruit quality:

Of paramount importance, is the fruit quality outturn. From an external quality point of view, no damage was noted at either 5.5°C or 8°C. However, some damage was noted at 2°C. In season 1, the greatest damage was found in the untreated controls, where all the fruits showed some damage characterized as chilling injury. The waxed fruit showed some damage, although this was too little to be considered of commercial importance, and is therefore not noted. No external damage was found in the bag treatments, although some of the polyethylene scrubber bags accumulated excessive moisture, which although not the case in this trial, could have resulted in high postharvest decay (Eksteen & Truter, 1985).

Bower *et al.* (2003) found a significant interaction between water loss and shipping temperature for ‘Fuerte’ and ‘Pinkerton’, and similar effects were noted by Pesis *et al.* (2000) for packaged mango. It would seem that the same is true for ‘Hass’, which would explain why there appears to be a high degree of external damage in the case of control fruit, at 2°C but not at the higher temperatures even though there was a greater water loss, while fruit stored at 2°C but protected from excessive water loss by packaging showed no damage. Similar results were found in the season 2 fruit, those from Limpopo had 80% of controls with external damage (Figure 2), while none of the waxed or bagged fruit were damaged. Although the mass loss of Limpopo fruit was recorded as 4.8%, it is estimated to have been higher, as some water loss would have occurred during transport. Work by Bower & Magwaza (2004) on ‘Fuerte’ indicated that the critical mass loss for inducing chilling injury symptoms at 2°C was approximately 6%, with a steep increase in damage with increasing mass loss. At 5.5°C this threshold was about 8%. At 8°C, no critical point was discerned. This appears to accord well with the data recorded for ‘Hass’.

From an internal quality perspective, no mesocarp discoloration was found in any of the fruit stored at 2°C. The only problems were found in the wax 2 treatment at 8°C, although it is believed that the flesh discoloration was due to pathological causes as stem-end rot was clearly associated. However, extensive experience of similar work on ‘Pinkerton’ in particular, (Van Rooyen & Bower, 2003), has shown that from an internal quality perspective, the lower the temperature used, the better the outcome, especially if fruit were sourced from an area of known quality defects.

Fruit CO_2 exchange and shelf life:

The CO_2 exchange of fruit from season 1 showed as expected, that the end of the storage period, respiration of fruit stored at 2°C was considerably lower than that at 8°C (Figure 4).

However, of further interest, was the evidence that postharvest treatment also modified the CO_2 exchange characteristics (Figure 5). The control fruits had a significantly higher net CO_2 exchange rate than the other treatments. The rest of the treatments, although not significantly different from each other, did show a tendency for a somewhat lower rate for fruit packed in the bags. This profile is important as not only did the control fruits lose more mass than the other treatments, but they appeared to have a higher respiration rate at the end of storage, with the bag packaging the lowest. Control fruits had the shortest shelf life, while the two packaged treatments softened most slowly, although there appeared to be no advantage of the ethylene scrubber bags. This is similar to the results obtained by Huysamer and Maré (2002). Ten days after discharge from the cold store, the control fruit was eating soft or beyond, while those in the bag packaging (2°C and 5°C storage) or only just reaching soft (8°C). The implication of these results is that the packaged fruit showed less ripening tendency during the storage period than the control fruit, and that as a consequence of the lower cumulative respiration, are likely to have used less of their carbohydrate reserves than the control fruit, and possibly also better than the waxed fruit. Liu *et al.* (2002) indicated that the C7 sugars manno-heptulose and perseitol may be implicated in the normal ripening physiology of avocado Bertling and Bower (2005) suggest, based on analysis of C7 sugars in various cultivars and known tendencies for postharvest disorders, that the residual pool of C7 sugars at both harvest and the end of storage, is an important determinant of quality and shelf life.

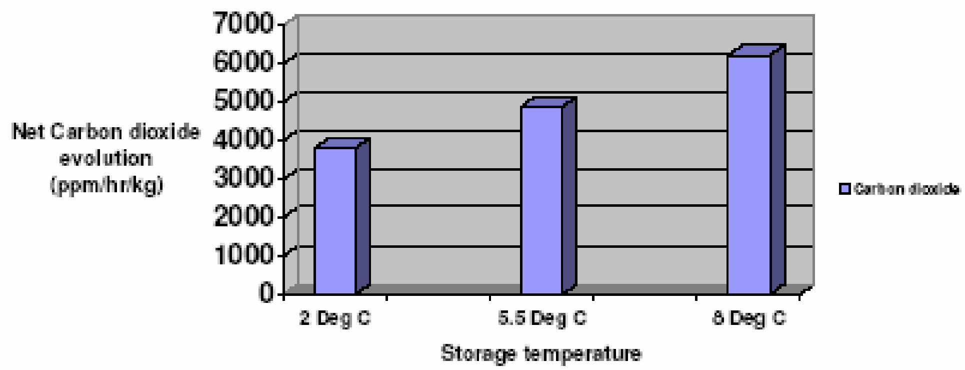

Figure 4. Net carbon dioxide evolution as influenced by storage temperature.

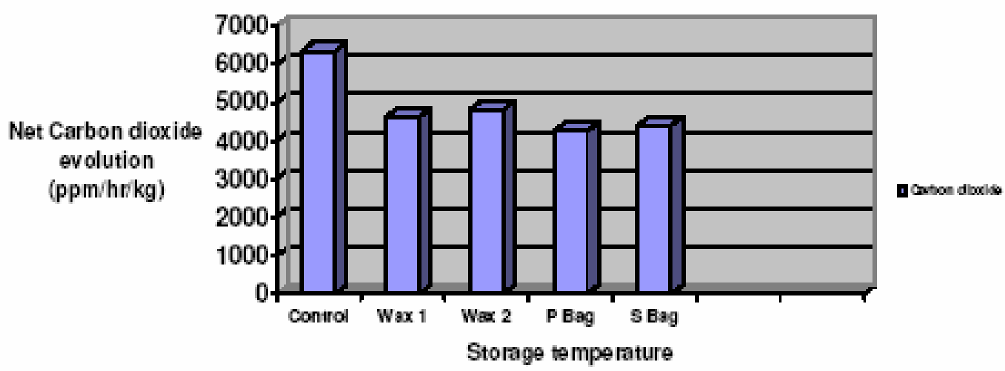

Figure 5. Effect of postharvest treatment on carbon dioxide evolution after storage.

Enhancing shelf life and decreasing disorders after discharge is clearly related to the fruit physiological changes during the shipping period as well as the later softening phase. It would be remiss to therefore not mention the potential use of 1-MCP for this purpose. Considerable work has been done using this compound on avocado. Lemmer *et al.* (2003) have shown that in the case of South African avocados, an extension of shelf life, together with a decrease in postharvest disorders, such as mesocarp discoloration, is possible. However, these results have not been found to be universally applicable. The long fruit ripening times after shipping may enhance the potential for body rots such as anthracnose. This may be particularly important where disease pressure is high, such as in New Zealand. While this technology may well be useful, there is probably considerable work still necessary for optimization under all circumstances.

Controlled atmosphere shipping has been used by most long distance shippers for some time, and has served the industries well. However, there is a cost implication, as well as experience which shows that outturns are not always as desired. Further refinement of postharvest procedures is thus desirable.

It would also be incorrect to ignore fruit physiological condition at the time of harvest. The potential for disorders related to fruit origin and maturity, is well established (Van Rooyen and Bower, 2002; Kruger *et al.* 2004). Knowledge of fruit origin and potential risk is thus desirable. This is done to some extent by South African and other exporters, taking into account assumed fruit maturity, calcium and other mineral element concentrations and orchard history. There are probably considerable opportunities for further work in this regard.

There are also opportunities for acclimatizing fruit to postharvest storage conditions, especially prolonged low temperatures. Although some work was conducted on 'Hass' (Bower, 2005), results were not conclusive, and further work will be needed. Work by Van Rooyen and Bower (2005) on 'Pinkerton' does, however, indicate some promise.

CONCLUSIONS

It is clear that by using the principles of reducing the postharvest stress induced by water loss and probably carbohydrate reserve depletion, prolonged shelf life and fewer physiological disorders can be achieved. Crucial to this philosophy is shipping at as low a temperature as possible, but at the same time restricting water loss, as there is a potentially deleterious temperature to water loss interaction. The use of micro-perforated polypropylene bags have been shown to be successful in this regard. The technology can be adapted to ship complete cartons or even pallets in this manner. The optimal shipping temperature is probably about 2°C to 3°C, but this may vary with fruit maturity, shipping time and fruit origin. Further work is being undertaken to determine these effects. The type of cooling also appears important, and in this regard, it is probable that hydrocooling will be advantageous. Again, this is being tested. It is also clearly necessary to ensure adequate pathogen control using both pre-and postharvest approaches. It is, however, suggested that the low temperatures advocated in the outlined technology will decrease potential decay as tissue senescence and collapse as well as fungal growth will be retarded, provided that the correct polypropylene bags with micro-perforations are used, ensuring that there is no build-up of free water in the bags.

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