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Effect of coatings and packaging on external and internal quality with emphasis on "cold injury"

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ABSTRACT

Previous work has shown the advantages of low temperature storage (2ºC) for decreasing the risk of mesocarp discoloration in 'Pinkerton'. However, at such temperatures external chilling injury is manifested in greenskins. An interaction between fruit water loss and skin damage was found, which could be modified by decreasing post-harvest water loss. Further work was, however, needed to evaluate packaging so as to enhance the economic viability of the proposed system. Micro-perforated polypropylene packaging was used in formats of single fruit packs, 10 fruit packs, and carton liners. These results were compared to those of the untreated controls and commercially waxed fruit. Storage was at 8ºC, 5.5ºC and 2ºC. Fruit quality was checked at 10, 20 and 30 days of storage. The highest mass loss occurred in the control fruit, with the lowest in the sealed packaging. Carton liners resulted in mass loss intermediate between waxing and sealed packaging. No chilling injury occurred at 2ºC for sealed packages, but waxing resulted in approximately 8% of fruit surface being damaged. Carton liners reduced this significantly, but did not eliminate it. Regression analysis indicated that chilling injury was considerably increased at a fruit mass loss of 8% and greater. It is suggested that the use of polypropylene packaging, carton liners or up-scaled derivatives such as pallet bags, would allow for the advantages of low temperature shipping to be realised, without external chilling injury.

INTRODUCTION

The work previously conducted by Van Rooyen & Bower (2002) indicated that low temperature storage (2ºC) as opposed to higher temperatures of 5.5ºC or 8ºC had a beneficial effect on internal quality, with particularly good results for 'Pinkerton' in terms of mesocarp discoloration. However, it was noted that external chilling injury became a concern at this temperature. The role of moisture loss in fruit senescence (and thereby possibly the symptom of chilling injury) was highlighted by King & O'Donoghue (1995). This led to attempts at decreasing water loss by using improved formulations of wax and polypropylene packaging (Bower *et al.,* 2003). In this work an interaction between water loss and chilling injury was found. In addition, relative humidity levels above 95% have been shown to restrict chilling injury and ripening rate for a number of products (Adato & Gazit, 1974) for avocado, Pesis *et al*. (2000) for mango and Xue *et al*. (1996) for banana. The concepts were further developed by Bower & Jackson (2003). While water loss was substantially controlled, this may not be the complete reason for the apparent decrease in chilling injury. Hardenburg (1971) noted that film packaging not only controlled water loss, but also altered the in-package atmosphere. Controlled atmosphere shipping has been noted to decrease the so-called external chilling injury which is often problematical in avocado. Kader (1985) advocated the use of modified atmosphere packaging for alleviating chilling injury of horticultural crops.

While the system of single fruits sealed in a micro-perforated polypropylene package with anti-mist coating appears to work well (Bower & Jackson, 2003), the system may be deemed too difficult to implement in many packhouses. Therefore, the systems needed to be modified in order to make them more commercially viable in terms of packhouse logistics. The modification, which consisted of carton liners and larger numbers of fruits packed into a sealed polypropylene bag, required testing for efficacy in terms of the potential for decreasing chilling injury, but at the same time maintaining good internal quality and ensuring hard fruit on arrival.

MATERIALS AND METHODS

Fruits of cultivar Fuerte were sourced from a commercial packhouse in the KwaZulu-Natal midlands. All fruits were of the same count and had normal packhouse procedures applied, except for waxing in the case of non-waxed fruit. Waxed fruit were collected from the pack line and had therefore been subjected to normal packing procedures. Fruits were transported to the laboratories of the Horticultural Science Dept. at the University of KwaZulu-Natal, and immediately prepared for simulated shipment. The following treatments were applied:

- Control (no treatment)
- Wax as applied in the packhouse
- Packed in cartons containing a carton liner of micro-perforated polypropylene material with anti-mist coating which surrounded the fruit but was not sealed
- Fruit packed as single units in micro-perforated polypropylene anti-mist coated bags, which were then sealed
- Fruits packed as units of 10 in micro-perforated polypropylene anti-mist coated bags, which were then sealed.

Once packed, fruits were placed in refrigerated containers with inlet temperatures set at 2ºC, 5.5ºC or 8ºC. One group of fruit was left at 20ºC to allow for ripening without storage. Actual temperatures and relative humidity surrounding the fruit was measured by means of HOBO data loggers. Fruits were stored at the designated temperatures for 10, 20 and 30 days before removal to 20ºC for ripening. Evaluations of fruit were made at the time of removal from storage as well as after fruit had softened to eating ripe as determined by a densiometer.

Evaluation of fruit included mass loss during the storage period calculated from fruit mass at packing and at removal from storage, incidence of chilling injury estimated as percentage of fruit surface covered by damage, and time in days for fruit to ripen after removal from storage.

Statistical analysis was carried out using 10 replications and analysis of variance by GENSTAT version 5.

The same procedures were carried out using 'Pinkerton'.

RESULTS AND DISCUSSION

Due to an error during the post-harvest analysis of the 'Pinkerton' fruit, the data set is not complete. However, the trends were the same as those for 'Fuerte' fruit, and therefore only the latter results will be depicted in detail.

Mass loss

The effect of treatment on mass loss is shown in Figure 1. As expected, the untreated fruit had the highest mass loss over time. However, the waxed fruit also lost significantly more mass (presumed to be water) than all the packaged fruits. The most efficient mass loss control was in the fruits sealed into polypropylene packages, with no differences between the P10 (10 fruits per pack) and single fruits per pack. The unsealed carton liner was less efficient than the sealed packs, but better than the waxed fruit. In the case of the control and waxed fruit, the lower the temperature, the less the overall water loss. A similar but less notable trend was observed in the carton liner treatment. The sealed packs, however, showed no difference as a result of temperature.

Further, and perhaps very important, was the rate of mass loss. The greatest mass loss occurred during the first ten days (first inspection time) of storage. In fact, most water loss and thus mass loss could be expected to occur during the initial cooling of the fruit (Wills *et al*., 1998). The sealed packs will reach a relative humidity of 100% or close to it fairly soon, and thus the continued water loss from the fruit will decrease rapidly, as was probably the case. The carton liner, not being sealed, was less efficient, but nevertheless better than both the waxed and untreated fruit, which continued loosing water into the container atmosphere, probably until fruit temperature reached that of the inlet air. Thereafter, some water loss could be expected to continue in the non packaged fruit, as was indeed the case. This is due to the container atmosphere continually being dried as it passes across the cooling coil, and the resultant deficiency of water being replaced down a concentration gradient from the fruit to the atmosphere. These principles are illustrated by Figure 2, showing the fruit mass loss over time at a temperature of 5.5ºC. It is clear therefore, that all forms of packaging used, in particular the sealed packs, were advantageous in terms of fruit mass (primarily water) retention. Considering the pattern of mass loss, it is likely that the stress on the fruit which may initiate cell damage and thus apparent chilling injury (King & O'Donoghue ,1995) occurred early in the shipping process.

Chilling injury

The external chilling injury incidence as affected by temperature and the post-harvest treatments, is shown in Figure 3. There was a highly significant ($p=0.01$) effect of both packaging treatment and temperature on the incidence of rind damage. The untreated fruits had very high levels of damage, which increased with decreasing temperature. The waxed fruit showed the same pattern, although with less chilling injury. Nevertheless, a mean of 25% of fruit surface was damaged at a storage temperature of 2ºC, while at 8ºC this was only 0.5%. This is in contrast to the packaged fruit, which showed almost no commercial damage even at 2ºC in the cases of the sealed packs. The carton liners did result in some fruit damage, being 5% at 2ºC. This was nevertheless considerably lower than the waxed fruit. Observation of chilling injury over time, indicated that visible damage primarily occurred during the period from 10 to 20 days of storage. This would be in accordance with both the work of Purvis (1984), who found chilling injury to be influenced by moisture loss, and Saltveit & Morris (1990), who indicated that the severity of injury is a function of the time at chilling temperatures. It is suggested that the initial moisture loss sensitised the fruit to chilling injury, and that damage became evident once a certain degree of cold duration had occurred. Physiological damage probably occurred during the first 10 days of storage. It is known that the atmosphere in the sealed bags becomes modified over time (Bower & Jackson, 2003). This may further decrease fruit damage in interaction with the lower water loss.

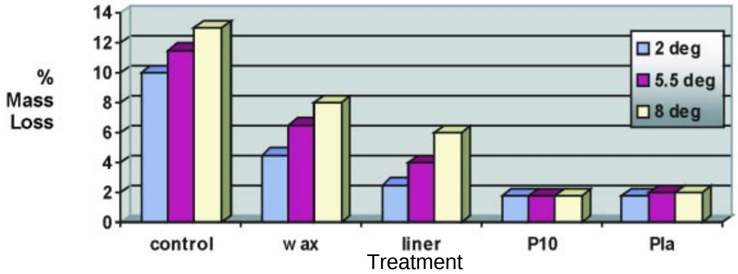

Figure 1. Percentage mass loss of fruit after 30 days storage as affected by temperature and post-harvest treatment. P10 and Pla refer to 10 fruits and 1 fruit packs, respectively

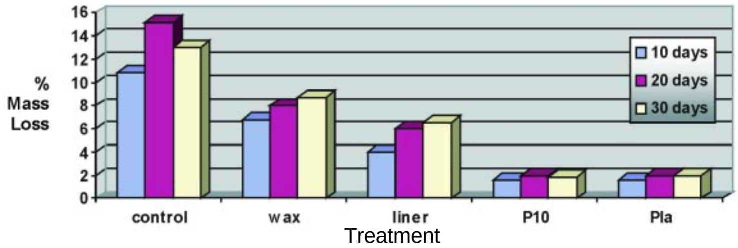

Figure 2. Percentage mass loss of fruit after 10, 20 and 30 days storage at 5.5ºC as affected by post-harvest treatment. P10 and Pla refer to 10 fruits and 1 fruit packs, respectively

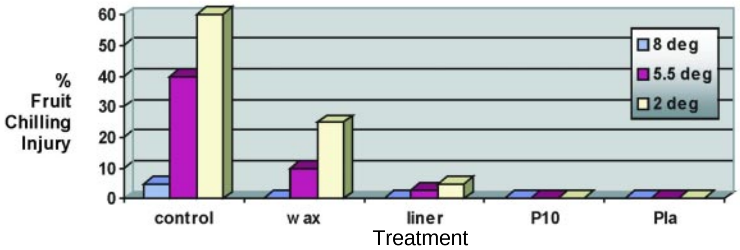

Figure 3. Percentage fruit surface damage after 30 days storage as affected by temperature and post-harvest treatment P10 and Pla refer to 10 fruits and 1 fruit packs, respectively

When plotting fruit mass loss against chilling injury for each temperature, it becomes clear that there is a threshold in each case, where further increases in mass loss results in rapidly increasing chilling injury. This is shown in Figure 4. Of note, the point of inflection of these curves appears to be between 6% and 8% mass loss. The lower the temperature the more sensitive the fruit appears to be to mass loss as related to chilling injury, with the point of inflection of the curve occurring at a slightly lower mass loss, and the slope of the curve being steeper once the point of inflection has been reached. This is in accordance with the findings of Bower *et al*., (2003) who determined that there was a significant interaction between mass loss and temperature in determining chilling injury. Based on these results, the potential for chilling injury can be calculated, provided one knows the air inlet temperature to the cold room or container, relative humidity of the air at that temperature, and the fruit temperature.

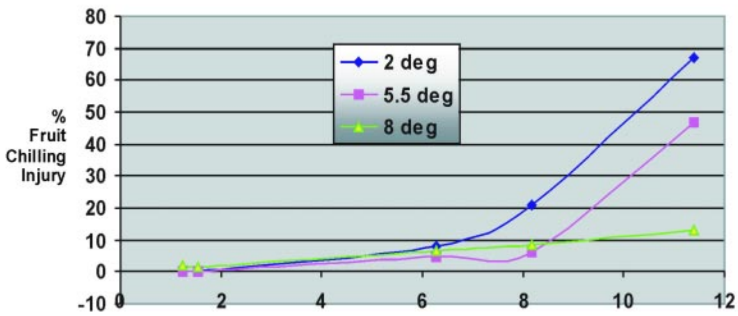

Figure 4. Effect of increasing mass loss and temperature on the incidence of fruit chilling injury

Time to ripen

The time taken for fruit to ripen after the 30 day storage period was significantly longer for the sealed packs than the other treatments, being approximately 7 days longer than waxed fruit. This can be ascribed to not only the water loss difference, but also the modified atmosphere which develops in the packs which could be expected to decrease the rate of ripening. The results may or may not be advantageous, depending on the objectives of the marketer. Fruit will, however, arrive at destination after shipping, in hard condition, which is of importance.

Fruit internal quality

No internal quality problems were found which could be ascribed to the packaging materials. This is despite the fact that observational measurements indicated high concentrations of CO_2 in the sealed packs by the end of the storage period.

Pathological disorders

An area of concern when using sealed packs could be enhanced post-harvest disease (Eksteen & Truter, 1985). However, provided the cold chain is maintained and packs opened once the chain is discontinued, the results obtained implied that this should not be a problem.

CONCLUSIONS

The role of mass loss (primarily water) control in preventing or substantially decreasing chilling injury has been confirmed. The results, however, go further than this, in that data has demonstrated that the period for greatest water loss is shortly after packing, primarily during the fruit cooling stage, although some loss does continue to occur throughout the shipping period. Further, the traditionally used wax formulation was the least effective (with the exception of untreated controls) in controlling the assumed water loss. As a consequence, chilling injury at low temperature was substantial, while in all the packaged treatments, including carton liners, fruit was commercially sound or had very little damage, even at the lowest temperature used.

Based on the results obtained, it is suggested that a packaging system using polypropylene material is a technically viable method of preventing external damage when shipping at low temperatures. This may be useful for internal quality maintenance or marketing purposes. It is further suggested that the material should be micro-perforated and coated with an anti-mist compound to reduce the possibilities of free water accumulation and therefore excessive post-harvest decay.

The individual packhouse logistics and marketing considerations may dictate the preferred method of packaging. Carton liners, although not as effective as sealed bags, were clearly more effective than wax coatings, and are logistically easy to use. Sealed bags were equally effective when single or multiple fruits were packed. Thus the system may possibly be scaled up to full carton or pallet bags, which could also be relatively simple to apply in the packhouse. From a marketing perspective, single or multiple fruits in a pack could under certain circumstances also be attractive.

The fact that fruit which is unwaxed can be shipped at standard or lower temperatures without chilling injury, has important consequences. In the opinion of fruit importers, waxed fruit appears more difficult to ripen in an even manner than unwaxed, when placed in ripening rooms for ready ripe programmes. Packaging and shipping in the manner outlined in this paper, particularly the carton liner concept (or larger scale sealed bags, which could be easily opened at the ripening facility), will be advantageous to fruit distributors. On the other hand, smaller sealed packs with a longer shelf life than standard carton packs, could also be advantageous under certain market conditions.

The data suggesting that water loss (and therefore potential for chilling injury) occurs to a large extent during the fruit cooling phase, implies that this stage should be a focus for further research. Although hydro-cooling is not used in South African avocado packhouses, it is employed to some extent elsewhere. As Wills *et al*. (1998) points out, the technique is more efficient than forced air cooling, and eliminates the fruit water loss effect which occurs while the fruit temperature exceeds that of the air. Research into hydro-cooling in combination with packaging methods as studied, should be conducted.

Overall, it is contended that if avocado fruit are packaged in suitable polypropylene material, they can be shipped at temperatures lower than presently used. This can decrease the risk of internal fruit quality disorders and enhance marketing opportunities. Fruit can also be shipped without wax, which could improve post-shipment ripening.

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