Effect of pre-harvest polymer coating on disease incidence, fruit appeal and physiological disorder incidence after harvest or extended cold-storage in 'Fuerte' or 'Ryan' avocados

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ABSTRACT

PolymerCoat coating (spraying) of avocados was considered as an alternative treatment to regular fungicide spraying during the fruit growth and development period to control disease (Circospora spot, stem-end rot and anthracnose). PolymerCoat was sprayed on 'Fuerte' and 'Ryan' avocados during their development. Coating commenced prior to start of rain in November 2006. The season was generally dry, not favouring pathogen proliferation. PolymerCoat was applied every three weeks or every three weeks after first applying copperoxychloride / Wenfinex oil, or was applied twice, just prior to the commencement of rain and afterwards in February, when the fruits were fully sized. Unsprayed fruits or fruits sprayed with copperoxychloride / Wenfinex oil served as controls. The effect of the treatments on severity and incidence of solar injury, fruit blemish, lenticel damage, or physiological disorders, was also assessed. The fruits were assessed for Circospora spot and skin disorders at harvest, and anthracnose and internal disorders after 28 days of cold-storage at 6°C.

Generally, the coated 'Fuerte' and 'Ryan' fruits were visually appealing, both at harvest and after extended cold-storage. Coating gave rise to risen lenticles in both varieties. This did not result in a detraction in appearance, however. In 'Fuerte', the incidence of disease and disorders was low (each <10%). Here, PolymerCoat was effective in reducing Circospora spot and anthracnose severity and incidence to low levels, and was as or slightly more effective in this regard than regular copper spraying. Differences regarding method of PolymerCoat application were not apparent. Circospora spot or anthracnose did not occur in 'Ryan'. Stem-end rot did not occur in either variety. PolymerCoat increased the severity and incidence of solar injury slightly in both 'Ryan' and 'Fuerte'. Lenticel damage or blemish markings did not occur in either variety. In 'Fuerte', coating gave rise to a slight increase in severity and incidence of grey pulp. Vascular browning severity and incidence were slightly reduced by coating, however. In 'Ryan', grey pulp or vascular browning incidence apparently bore no relation to treatment.

It might be concluded that PolymerCoat coating is an effective measure to control disease in 'Fuerte' avocado without significantly affecting the fruits negatively with regard to lenticel damage, blemish, solar injury or physiological disorders. The results endorse additional research to verify and optimise the use of PolymerCoat in a number of varieties, and during wetter seasons.

INTRODUCTION

Avocados are susceptible to pathogen infection prior to harvest. *Pseudocercospora purpurea* causes raised, black, shiny spots prior to harvest, which are frequently associated with cracking and corking of the lenticles (Circospora spot) (Deighton, 1976; Darvas, 1982). Anthracnose (*Colletotrichum gloeosporioides*) and stem-end rot (*Dothiorella* spp., *Lasiodiplodia theobromae*, *Thyronecria pseudotrichia*, *Colletotrichum gloeosporioides*, and *Phomopsis perseae*, and *Fusarium descemcellulare*) are significant diseases, causing lesions after harvest when ripening occurs (Darvas and Kotze, 1979ab; Prusky, *et al.*, 1990; Coates, *et al.*, 1993a). Pathogen spores originate from regions of the tree canopy (dead leaves, dead twigs, dead branches, and possibly infected, living leaves) reaching the fruits via water flow, insect movement and wind (Peterson, 1978; Fitzell, 1987; Pegg and Coates, 1993; Coates, *et al.*, 1993a; Pohronezny, *et al.*, 1994). In the case of stem-end rot, infection may also occur endophytically through the pedicle (Johnson, *et al.*, 1992; Johnson and Kotze, 1994). Pre-harvest sprays of benomyl and copperoxychloride effectively control these diseases (Darvas and Kotze, 1987; Lonsdale and Kotze, 1989; Lonsdale, 1991; Lonsdale, 1992; Duvenhage, 1994; Pegg, *et al.*, 2002). In exporting avocado fruits to the EU, the fruits remain in transit storage for 21 to 28 days, and are generally shipped at 3 to 7°C. Following wet seasons, fruit loss due to Circospora spot and anthracnose is particularly significant, despite rigorous pre-harvest spraying (general obs.). Sporulation of *Colletotrichum gloeosporioides* and *Pseudocercospora purpurea* is favoured by wet, humid conditions (Peterson, 1978; Coates, *et al.*, 1993a; Pohronezny, *et al.*, 1994).

PolymerCoat is an inert polymer coating formulated to coat plant surfaces to reduce stress resulting from moisture loss. The coating is permeable to gasses, including water vapour. In the present study, PolymerCoat, in being sprayed to cover the entire peel of the fruit, was considered a possible barrier preventing spores from coming into contact with the peel (exocarp). Fruit coating (**Figure 1**) prior to the onset of rain may prevent infection, and thus be a viable alternative to copper spraying. It might be expected that earlier (pre-rain event) as opposed to later (post-rain event) coating will be more effective in preventing disease infection, due to the enhanced time of protection resulting from earlier coating, and the observations of wet conditions favouring pathogen sporulation. Previous coating studies having these objectives were not found by the author. Coating of avocados after harvest has been considered as a measure to delay ripening and, thus, increase shelf-life.

Figure 1. Coated 'Fuerte' fruit.

Coating of avocados with Semperfresh (a fatty acid-sucrose ester mixture) after harvest gave rise to reduced weight loss and prolonged the time until ripening (Flores, 1992). An effect on flavour on ripening was not detected. Ripening initiation was delayed and storage performance enhanced in avocados treated with an edible-film coating (Bender, *et al.*, 1993). Coated fruits exhibited a lower respiration rate, lower ethylene production, and higher flesh firmness than non-coated fruits.

In the current study, spray coating of 'Fuerte' or 'Ryan' avocados as a non-chemical alternative to controlling Circospora spot, stem-end rot, and anthracnose was of primary consideration. The effect of coating on solar injury, lenticel damage, skin-blemish, and physiological disorders, was also evaluated. Fruit evaluations were performed before and after 28 days of cold-storage at 6°C, and comparison was made with the generally adopted commercial practice of regular copper spraying to prevent infection prior to harvest, and with untreated fruits.

MATERIALS AND METHODS

In each of two bearing orchard blocks, a 'Fuerte' block and a 'Ryan' block, 50 trees were selected. In each of the blocks the following were carried out:

In each tree, twenty fruits, well distributed on and in the canopy, were labelled. The following treatments were carried out on the labelled fruits in each of ten trees.

a) No treatment was applied to the fruits (Control).
b) PolymerCoat was sprayed on the fruits every three weeks (Silicon).
c) Copperoxychloride / Wenfinex oil was applied just prior to coating, after which PolymerCoat was spray applied to the fruits every three weeks (CuSilic).
d) PolymerCoat was applied twice, once on October 31, 2006, and once in February (February 13, 2007), when the fruits had attained full size (Silicx2).
e) Copperoxychloride / Wenfinex oil (Cu) was applied to the fruits every three weeks.

Application in every instance was made with a knap sack sprayer. PolymerCoat was diluted, having been applied at half strength. Copperoxychloide was applied at the rate of 300 g per 100 l, and Wenfinex oil at the rate of 300 ml per 100 l.

All treatments commenced on October 31, 2006, just prior to the commencement of rain. Conditions became humid and wet during early November, 2006. Rain had not started by Nov. 2, the second date of coating. Appreciable rain occurred on Nov. 4 and 5 (25 to 30 mm on each of the days, recorded by a rain gauge), and again on Nov. 18, when more than 100 mm was recorded. Copper was first applied on Oct. 31. Appreciable rain occurred again in late December (Dec. 28 to 31). Conditions during January and February, 2007, were dry. Some rain occurred during April, 2007.

The fruits were harvested on May 2, 2007 ('Fuerte') and August 27 ('Ryan'), and immediately placed in a laboratory maintained at 20°C (±0.5°C). At this stage, the extent of solar injury and Circospora spot were estimated in each fruit. Solar injury was rated. A rating of "0" was given if signs of injury were absent, a rating of "1" if injury was present, but localized to a small area, a rating of "2" if approximately 1/3 of the fruit was affected, a rating of "3" if 1/3 of the fruit was affected, and a rating of "4" if the entire fruit was affected. Circospora spot coverage was estimated in terms of a percentage. The percentages assigned were 0, 25, 50, 75 or 100. Blemish markings and lenticel damage did not occur.

On May 7 and August 31, 2007, the fruits removed from each tree were placed into each of two 4 kg avocado cartons, and then into a cold-room maintained at 6°C (±0.5°C). Carton packing in the cold-storage room was carried out in orchard randomisation sequence to retain an effect of "blocking" (experiment layout). After 28 days, the cold-room temperature was increased to 20°C. At this stage, the degree of anthracnose, grey pulp and vascular browning was estimated in each fruit once softening had commenced (densimeter reading <60). Fruit firmness was assessed with a densimeter (Heinrich Bareiss, Obischingen, Germany). The number of anthracnose lesions was counted, after which the fruit being evaluated was cut through from the stem-end downwards. After cutting, the extent to which each of the physiological disorders (grey

pulp and vascular browning) affected the pulp was estimated. Estimation was carried-out as was solar injury. Stem-end rot and pulp spot did not occur.

There were 10 treatment replicates, each comprising 20 fruits, in a Randomized Complete Blocks design. The tree or double-carton averages were subjected to Analysis of Variance. Mean separation was based on the 5% LSD criterion.

RESULTS

'Fuerte'

The average severity and incidence of external and internal disorders was low. Most of the fruits were of good quality at harvest (**Figure 2**) and after extended cold-storage. The coated fruits developed risen lenticels. This did not detract from their appearance, however. PolymerCoat adhered to the fruits prior to and after harvest. Coating once the fruits were attained their full size was observed not to be necessary.

Figures 4 and **5** show the average severity or incidence of solar injury. PolymerCoat gave rise to a slight increase in susceptibility to solar injury (**Figure 3**), only the sun-exposed fruits having been affected.

Figures 6 and **7** show the average percentage cover and the incidence of Circospora spot.

The incidence of Circospora spot was less than 10% (**Figure 8**). The average cover and incidence was reduced by copper as well as PolymerCoat application. PolymerCoat was as effective as copper in reducing the severity and incidence of this disease. In the coated fruits, differences in relation to application method were not apparent.

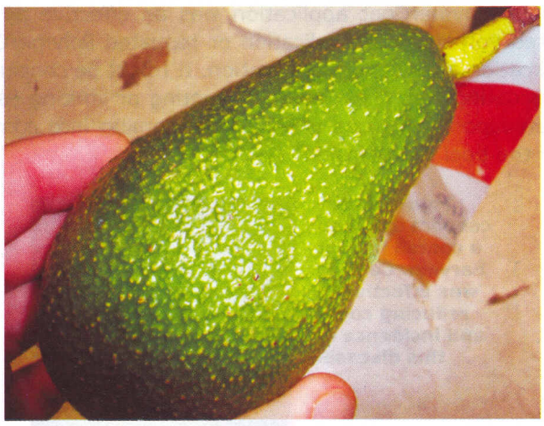

Figure 2. Coated 'Fuerte' fruit at harvest showing risen lenticels. After harvest and cold storage, the fruits were generally of good quality, both externally and internally.

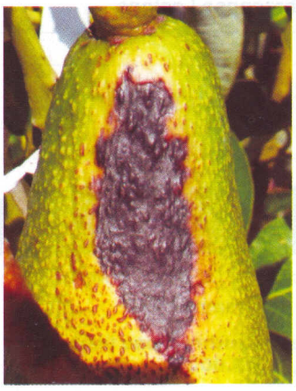

Figure 3. PolymerCoat slightly increased susceptibility to solar injury.

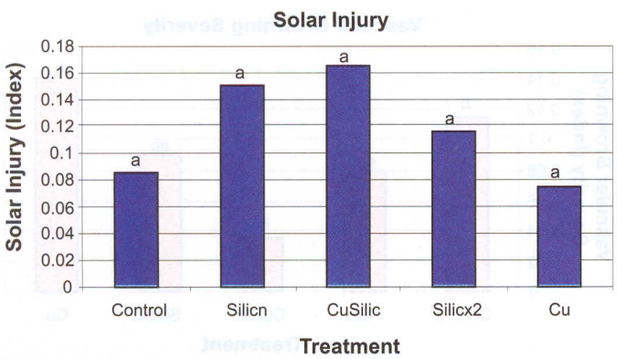

Figure 4. Average severity of solar injury in relation to treatment (p_{treat} <0.26).

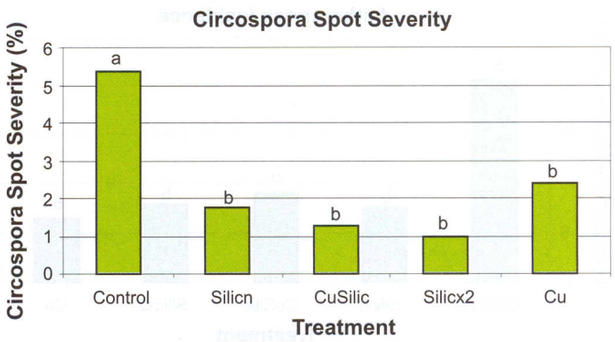

Figure 6. Average cover of Circospora spot in relation to treatment (p_{treat} <0.02).

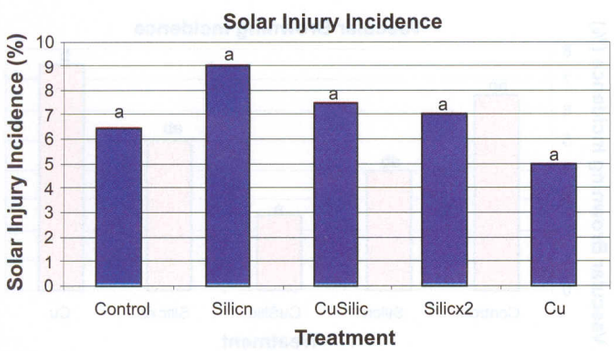

Figure 5. Incidence of solar in injury in relation to treatment (p_{treat} <0.76).

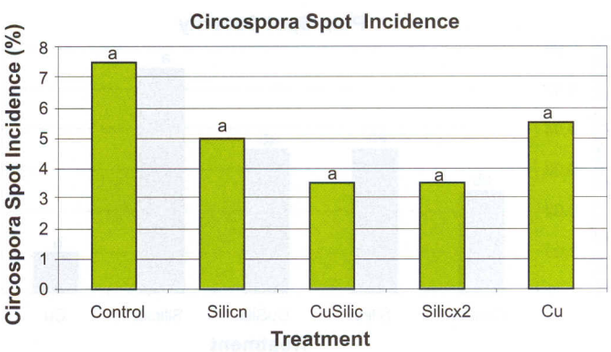

Figure 7. Incidence of fruits showing Circospora spot in relation to treatment (p_{treat} <0.34).

Double PloymerCoat application was as effective as repeated PolymerCoat application or repeated PolymerCoat application after copper application. It might be concluded that coating was effective in preventing or limiting *Pseudocercospora purpurea* conidia from coming into contact with the peel of the fruits.

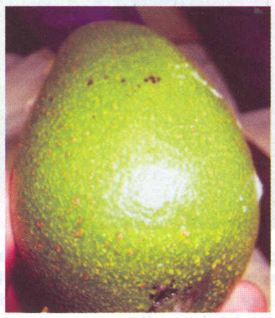

Figure 8. Circospora spots on a coated fruit at harvest. Coating was effective in reducing cover and incidence of this disease.

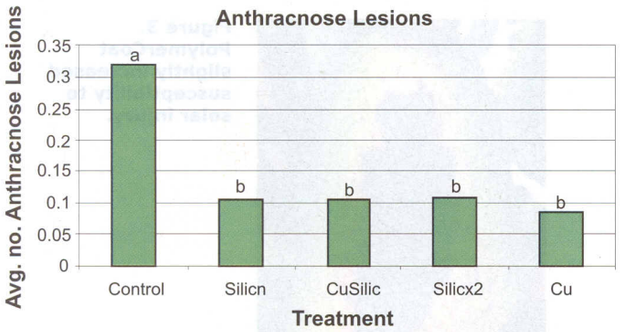

Figure 9. Average number of anthracnose lesions per fruit in relation to treatment (p_{treat} <0.002).

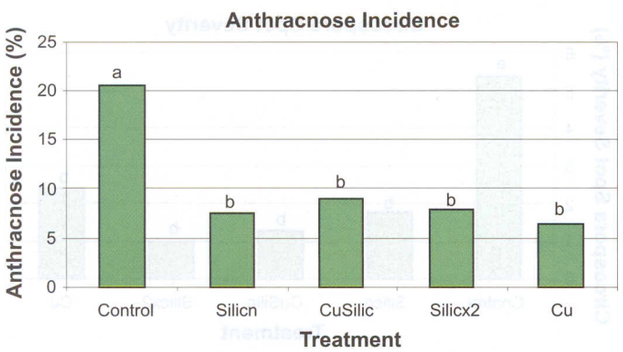

Figure 10. Anthracnose incidence after cold storage in relation to treatment (p_{treat} <0.001).

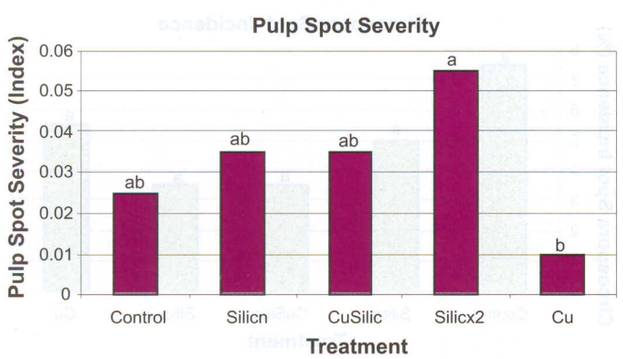

Figure 11. Average grey pulp severity in relation to treatment (p_{treat} <0.30).

Figures 9 and **10** show the average number of anthracnose lesions per fruit or the incidence of anthracnose after cold-storage.

Coating or copper application were effective in reducing anthracnose, and equally effective in this regard. In the coated fruits, differences in relation to application method were not apparent. Double PloymerCoat application was as effective as repeated PolymerCoat application or repeated PolymerCoat application after copper application.

Figures 11 and **12** show the severity or incidence of grey pulp.

The incidence of grey pulp was less than 10%. Its severity and incidence were slightly elevated in the coated fruits.

Figures 13 and **14** show the severity or incidence of vascular browning. Incidence was low, being less than 10%.

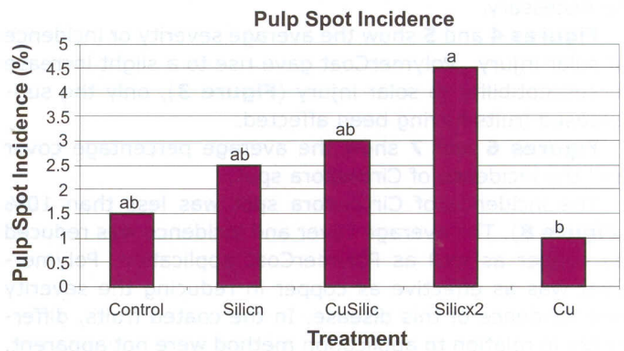

Figure 12. Incidence of grey pulp in relation to treatment (p_{treat} <0.26).

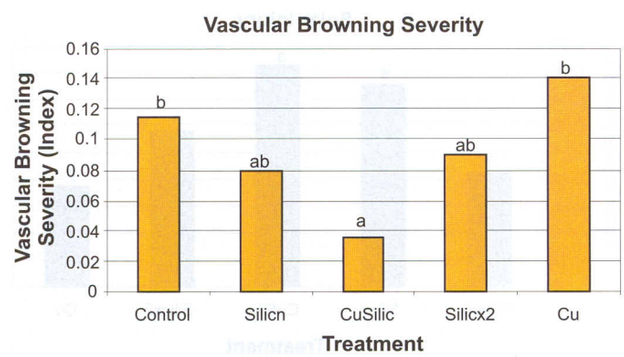

Figure 13. Average severity of vascular browning in relation to treatment (p_{treat} <0.07).

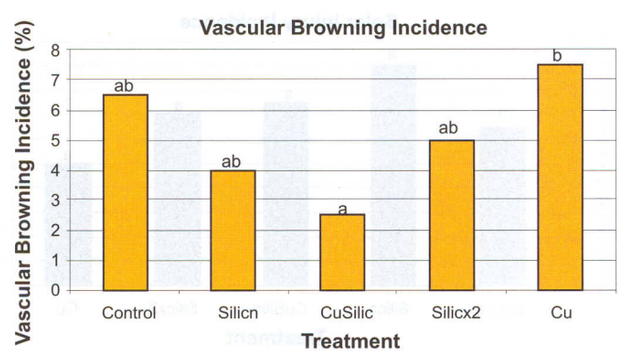

Figure 14. Incidence of vascular browning in relation to treatment (p_{treat} <0.13).

The severity and incidence of vascular browning was slightly reduced in the coated fruits. Differences relating to coating method were not apparent.

Typical grey pulp and vascular browning symptoms observed are shown in **Figures 15** and **16**.

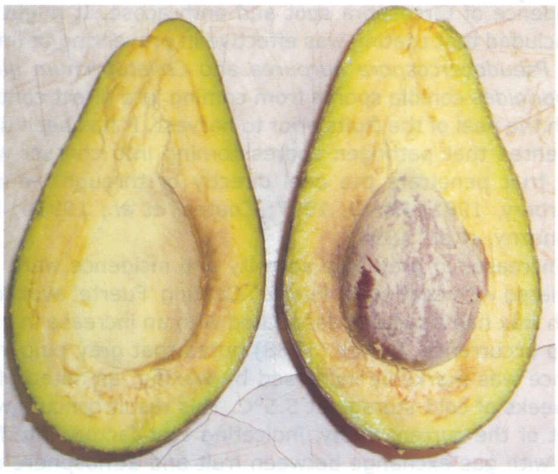

Figure 15. Grey pulp in a 'Fuerte' fruit.

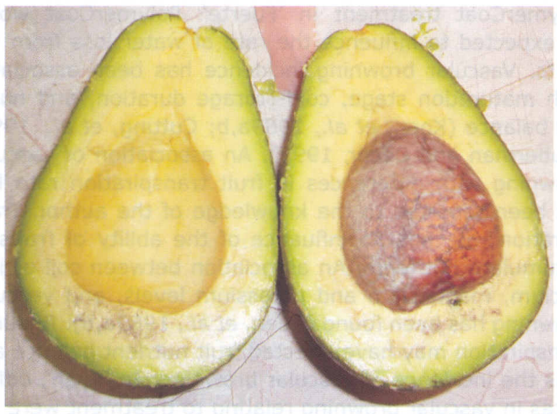

Figure 16. Vascular browning in a 'Fuerte' fruit.

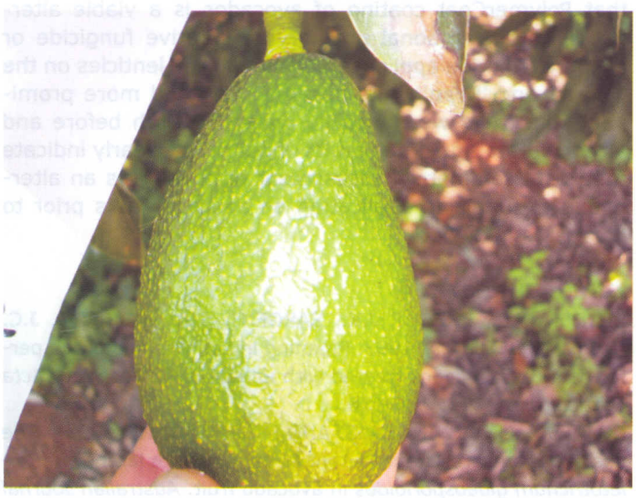

Figure 17. 'Ryan' fruit coated with PolymerCoat. Note the increased prominence of the lenticles.

'Ryan'

Figure 17 shows a 'Ryan' fruit coated with both copperoxychloride and PolymerCoat. The fruits of this variety were generally of good quality at harvest and after extended cold-storage. Circospora spot did not occur. Some fruits exhibited solar injury. Anthracnose was not observed after extended cold-storage.

Figures 18 and **19** show the severity and incidence of solar injury.

As in 'Fuerte', PolymerCoat gave rise to a slight increase in susceptibility to solar injury, only the sun-exposed fruits having been affected.

Figures 20 and **21** show average grey pulp severity or incidence of grey pulp. The occurrence of this disorder was low, being less than 5%. Differences in relation to treatment were not apparent.

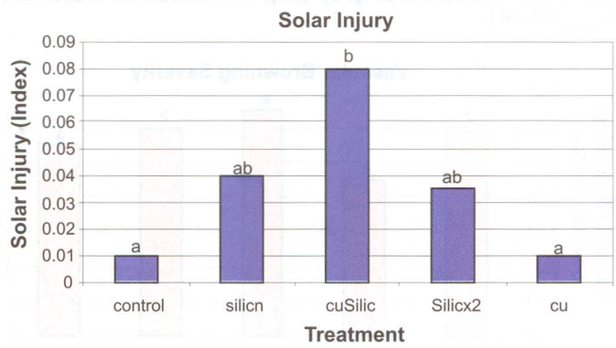

Figure 18. Average severity of solar injury in relation to treatment.

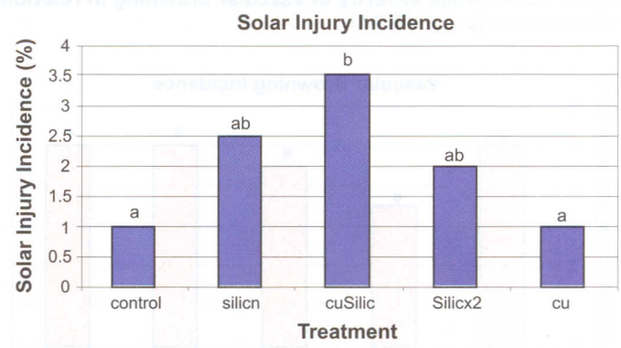

Figure 19. Incidence of solar injury in relation to treatment.

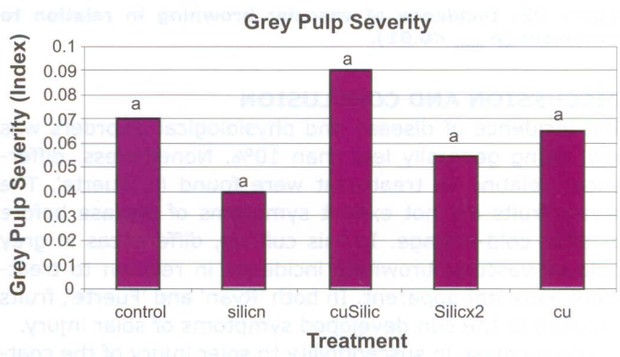

Figure 20. Average severity of grey pulp in relation to treatment (p_{treat} <0.67).

Figures 22 and **23** show average vascular browning severity or incidence of vascular browning. The occurrence of this disorder was low, being less than 5%. Differences in relation to treatment were not apparent.

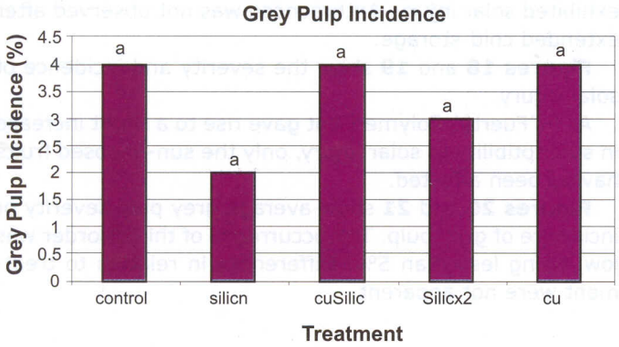

Figure 21. Incidence of grey pulp in relation to treatment (p_{treat} <0.74).

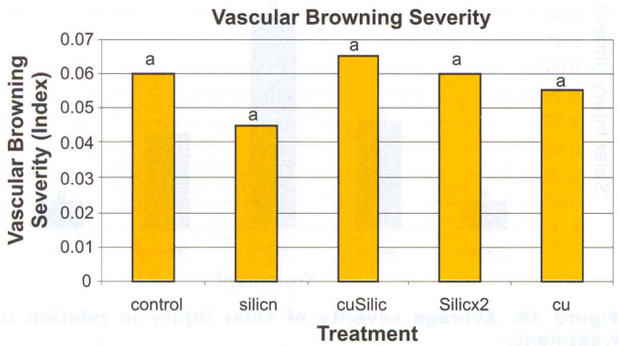

Figure 22. Average severity of vascular browning in relation to treatment (p_{treat} <0.94).

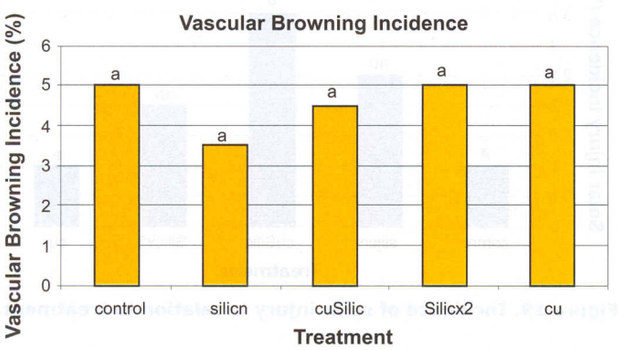

Figure 23. Incidence of vascular browning in relation to treatment (p_{treat} <0.91).

DISCUSSION AND CONCLUSION

The incidence of disease and physiological disorders was low, being generally less than 10%. Nonetheless, differences relating to treatment were found in 'Fuerte'. The 'Ryan' fruits did not exhibit symptoms of disease before or after cold-storage. In this cultivar, differences in grey pulp or vascular browning incidence in relation to treatment were not apparent. In both 'Ryan' and 'Fuerte', fruits exposed to the sun developed symptoms of solar injury.

The increase in susceptibility to solar injury of the coated fruits might be explained in terms of reduced transpiration, and thus cooling, at the sites of direct sun exposure. In the coated fruits, differences in relation to coating method were not apparent. There was no clear evidence for multiple coating or copper in addition to multiple coating, as opposed to double coating, increasing the likelihood of solar injury.

The general incidence of anthracnose or Circospora spot was low. Coating was effective in reducing the severity and incidence of Circospora spot and anthracose. It might be concluded that coating was effective in preventing or limiting *Pseudocercospora purpurea* and *Colletotrichum gloeosporioides* conidia spores from coming into direct contact with the peel of the fruits prior to harvest. It has been documented that pathogen spores coming into contact with the fruit penetrate the peel directly or through wounds (Parbery, 1981; Fitzell, 1987; Coates, *et al.*, 1993b; Pohronezny, *et al.*, 1994).

Increases in grey pulp severity and incidence were associated with coating in 'Fuerte'. Coating 'Fuerte' avocados with wax has also been associated with an increase in grey pulp occurrence. Rowell (1988) noted that grey pulp incidence was markedly increased by waxing, as noted after 4 weeks of cold-storage at 5.5°C. This result concurs with that of the current study, indicating that factors interfering with gas exchange between fruit and atmosphere can adversely affect the pulp.

Reductions in vascular browning were associated with PolymerCoat treatment in 'Fuerte'. PolymerCoat would be expected to influence the rate of water loss from the fruits. Vascular browning incidence has been associated with maturation stage, cold-storage duration, and nutrient balance (Koen, *et al.*, 1989a,b; Cutting, *et al.*, 1992; Zauberman and Décor, 1995). An association of vascular browning with differences in fruit transpiration rate has not been reported to the knowledge of the author. Transpiration rate has an influence of the ability of fruits to accumulate nutrients. An association between soil or leaf calcium, magnesium and potassium levels, and vascular browning has been found (Koen, *et al.*, 1989a,b). Reduced transpiration may have affected fruit nutrient balance and thus the incidence of vascular browning. In 'Ryan', differences in vascular browning relating to treatment were not apparent.

In general view of the results, it might be concluded that PolymerCoat coating of avocados is a viable alternative to conventional pre-harvest curative fungicide or copperoxchloride application. Although the lenticles on the 'Fuerte' and 'Ryan' fruits became risen and more prominent, the fruits were visually appealing both before and after cold-storage. The results of our study clearly indicate that semi-commercial assessment of coating as an alternative to fungicide application on avocado fruits prior to harvest is justified.

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