The feasibility of a hot water treatment for South African avocados (*Persea americana* [Mill.] cv Hass)

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ABSTRACT

The South African Avocado Growers' Association is currently trying to develop a system to deliver high-quality avocados into new markets while complying with strict phytosanitary requirements. There is potential that a hot water treatment of avocados can provide a number of benefits but there are differences in opinion in the efficacy for South African avocados, which formed the subject of this investigation. Three batches of fruit through the 2006 season were used from Tzaneen and a single batch of fruit from Howick, late in the season. Fruit were subjected to a hot water bath of 36˚C, 38˚C or 40˚C for 5, 15 or 30 minutes. Two storage temperatures were used: 1˚C and 5.5˚C. The hot water treatment shortened the ripening period; improved colour development in early season fruit; reduced the severity and occurrence of anthracnose, stem-end rot, pulp spot and external chilling injury. The most beneficial temperature was 38˚C and the optimal time was 15 to 30 minutes. The use of hot water treatments does seem beneficial for avocados but further investigations are needed, particularly to determine the physiological basis behind these observations. These findings are in accordance with investigations done by Woolf and Hofman in Australia and New Zealand.

INTRODUCTION

The South African avocado industry is export orientated, necessitating large volumes of fruit being exported by sea. As the European avocado market reaches saturation, it will become necessary to find alternative markets such as some new markets. To access these markets long transportation times are required and in addition more effective post-harvest treatments to prevent chilling injury are needed, as Japan and the USA require a cold disinfestation treatment for fruit fly (*Ceratitis cosyra, C. rosa* and *C. capitata)* (De Villiers *et al*., 2001; Hofman *et al.*, 2002a) and false codling moth (*Cryptophlebia leucotreta* Meyrick). This is achieved by storing the fruit at temperatures close to 0˚C for up to 24 days – resulting in chilling injury to avocado fruit (Hofman *et al.*, 2002b). Although much research has been conducted to improve the post-harvest management of avocados, further research is needed on this particularly difficult commodity (Hofman *et al.*, 2002b).

Avocados, being subtropical, are sensitive to low temperatures and may require mitigating treatments before being placed in cold storage to make the fruit more resistant to low temperatures to ensure high quality fruit to consumers in distant markets, especially if the importing country requires phytosanitary certification. With the added increasing demand for chemical-free produce, non-chemical techniques to disinfest fruit and preserve fruit quality are required (Klein and Lurie, 1992; Hofman *et al.,* 2002a). It was been found that many commodities are more resistant to chilling injury after high temperature conditioning (Wheaton and Morris, 1967). Woolf *et al.* (1996) found that a heat treatment of 38˚C for 60 min reduced chilling injury at 0.5˚C and 2˚C and suggested that a slightly higher temperature (39˚C or 40˚C) for 30 to 60 min could be as, if not more, effective. Cold-stored, pre-heated fruit ripened normally, tissue breakdown was significantly reduced and other disorders were slight, and fruit were of acceptable quality. Hofman *et al.* (2002a) also found that hot water treatment (HWT) of avocado fruit significantly reduced chilling injury. These authors found that a treatment of 40˚C to 41˚C for 30 min was the most effective regime for reducing chilling injury and fungal infections. However, Kritzinger *et al.* (1998) were not been able to repeat these results, possibly due to differences in the 'Hass' selections or climate. This investigation's aim was to determine the feasibility of heat treating South African avocados to reduce chilling injury, and if successful, which treatment regime would be the most effective. To be useful, the selected treatment must be able to be integrated into the packing line. The treatment needs to be as short as possible so as not to cause a bottleneck in the packhouse. If a successful hot water treatment is found, South African avocados could be sent to new markets, enhancing total sales opportunities and ultimately resulting in higher profits for growers.

MATERIALS AND METHODS

Fruit were obtained from Tzaneen (Limpopo) and Howick (KwaZulu-Natal). Three batches of fruit from Tzaneen were pre-waxed and delivered to Pietermaritzburg in a refrigerated truck at 6˚C. A single batch of fruit from Howick was not waxed and was transported to Pietermaritzburg for processing within a few hours of harvest.

The fruit were hot water treated, weighed and put into cold storage. The hot water treatment had three temperatures: 36˚C, 38˚C and 40˚C and three time durations: 5, 15 and 30 minutes. Fruit were stored at 1˚C or 5.5˚C. The control fruit were untreated and placed directly into cold storage. The number of replications per treatment was 10 fruit.

The fruit were visually assessed weekly for external chilling injury and rated on a scale of 1-20 where 1 = no damage and 20 = damage of the entire surface of the fruit. After 30 days the fruit were removed from cold storage, weighed and visually assessed for external chilling injury and allowed to ripen in a laboratory at approximately 25˚C. On ripening the fruit were weighed and exocarp colour development, external chilling injury, shrivel, lenticel damage, anthracnose, stem-end rot, vascular browning, pulp spot and mesocarp discolouration were assessed. Other defects were also observed.

The statistical design was a Completely Randomized Design (CRD) with Whole and Sub-Plot treatments. The Whole Plot treatment was harvest date and the Sub-Plot treatment the hot water treatment and storage. Statistical analysis was done using Genstat version 9.1.

RESULTS

External chilling injury

There was little significant difference between many of the treatments within each harvest date. Comparing external chilling injury (ECI) of fruit stored at 1˚C, the early season fruit had the least damage at the 40˚C, 15 min HWT. For the midseason fruit the most effective HWT was the 36˚C, 5 min, but the control fruit had comparable damage. The fruit from the late harvest and from Howick that were given a 38˚C, 30 min HWT had the least ECI. Of all these treatments, only the 40˚C, 15 min HWT for the early harvest had significantly less ECI than the control. During storage, heat-treated fruit often exhibited more severe ECI but after ripening the control fruit appeared to have increased ECI, while the ECI of the heat-treated fruit appeared to be reduced after ripening (**Figure 1**). At 1˚C storage temperature, this was noticed in all the treatments except the 40˚C, 30 min treatment. This change in observation may be due to the increased colour development of the treated fruit masking the ECI.

Colour development

All the HWTs of the early harvest fruit showed improved colour development. Three treatments were significantly better: 38˚C, 30 min; 40˚C, 5 min; and 40˚C, 15 min. While there was some improvement in exocarp colour in the other batches, none of the treatments proved significantly better.

Spread of ripening

Spread of ripening is defined as the number of days to maximum ripe fruit, within a treatment, starting once the first fruit ripened, provided 50% of the fruit in the treatment ripened. The HWT reduced the spread of ripening across all four harvests (**Table 1**). The treated fruit had a very similar spread of ripening (excluding the midseason fruit stored at 5.5˚C) of one to three days.

DISCUSSION

The physiological explanation for the efficacy of heat shock treatments is normally that the organism or tissue produces heat

Table 1: Most effective HWTs for the reduction of ripening period, with spread of ripening, in days, for the control and the most effective HWT. Dashes (-) indicate that less than 50% of the fruit ripened.

Harvest	1˚C Storage			5.5˚C Storage		
	Best HWT	Spread of ripening		Best HWT	Spread of ripening	
		Control	HWT		Control	HWT
Early	40˚C,30min	6	3	38,15min	-	1
				40˚C,30min	-	1
Mid	38˚C,30min	-	2	38,30min	8	5
Late	38˚C,5min	6	2	40,15min	9	2
Everdon	40˚C,30min	8	3	40,15min	6	2

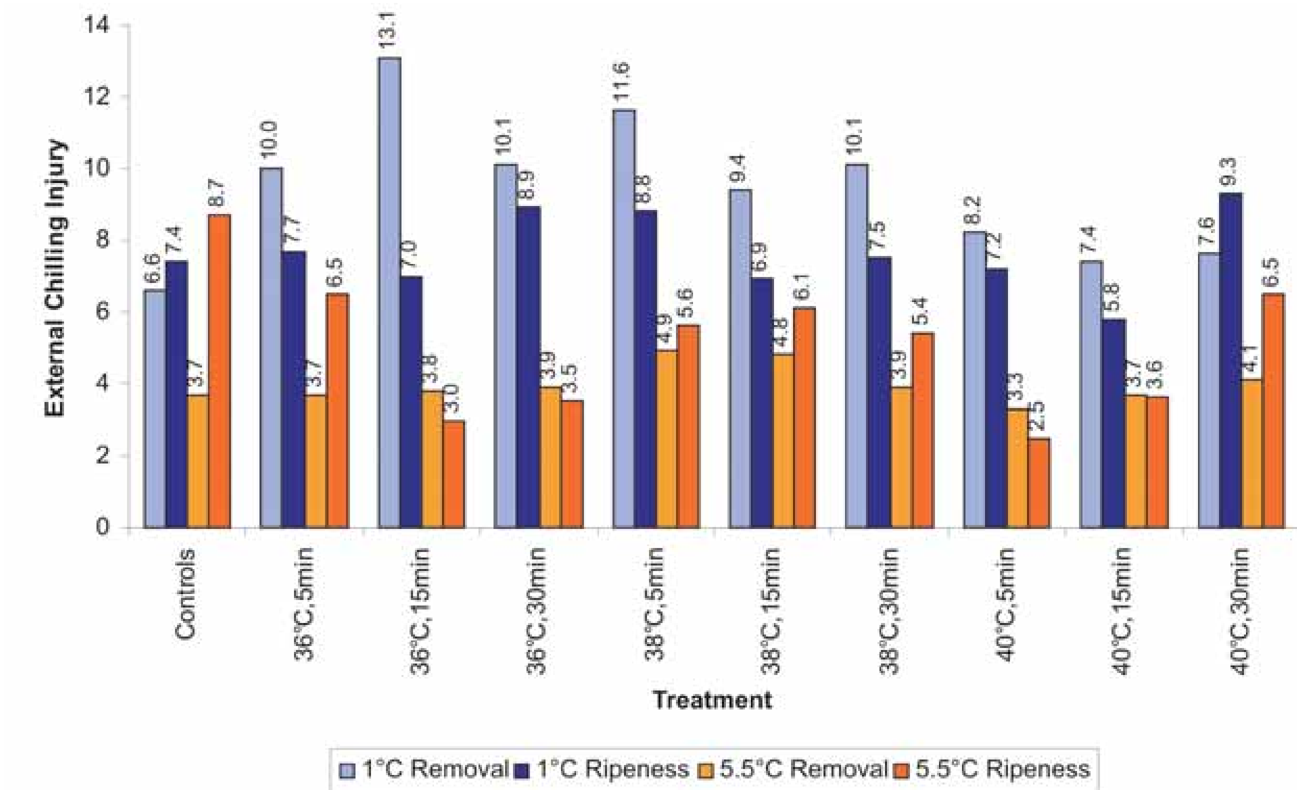

Figure 1: External chilling injury (rated on a scale of 1-20 where 1 is no damage and 20 is 100% damage) of early season fruit at removal from cold storage and at ripeness. To compare between two treatments, LSD = 1.4. To compare within a treatment, at the same temperature, LSD = 2.6.

shock proteins (HSPs) to protect cellular constituents from heat damage. This hypothesis seems less likely in this case because the benefit of the HWT only became apparent after ripening. During storage the treated fruit often exhibited more severe damage than the control fruit. This suggests that HSPs are not the physiological reason behind the efficacy of the HWTs for avocados and if HSPs are involved in the reduction of chilling injury, they are not the only mechanism. This is in agreement with Woolf *et al.* (1996) who isolated HSP mRNA but concluded that "it would be overly simplistic to suggest that HSPs alone are the mechanism of chilling injury reduction by heat treatments". The temporal occurrence and efficacy of HSPs needs to be elucidated for their benefit to be quantified.

Across all the hot water treatments, the treated fruit showed greater external chilling injury during storage. It was only once the fruit ripened that the treatments became visually effective. This apparent reduction in external chilling injury is most likely due to improved colour development masking the chilling injury. While there was significantly improved colour development only in the fruit from the earliest harvest, there was a trend towards improved colour of the fruit from the later harvests. The colour of the control fruit for the midseason, late harvest and fruit from Howick was better developed, so any improvement proved insignificant. The additional stress from the HWT may cause greater anthocyanin synthesis as a protective mechanism. This would mean that green-skinned avocados such as 'Fuerte' and 'Pinkerton' would probably not benefit from this aspect of heat shock because those cultivars do not produce anthocyanins in the exocarp as 'Hass' does.

From results in the industry, ethylene treatment of South African fruit does not provide a means of adequately manipulating the ripening pattern. South African fruit exhibit asynchronous or a total lack of ripening, i.e. some fruit ripen a few days after removal from cold storage, some ripen a week later and some do not ripen at all. This indicates that there is a problem with the ripening mechanism of the fruit. This may be due to damage to the ethylene receptor, the synthesis of ripening enzymes or the functioning of these enzymes. Heat shock appeared to reduce the spread of ripening, but the physiological reason for this improvement is presently unknown. If the effect of the HWT was to induce the synthesis of HSPs, the membrane-bound ethylene receptor should have been protected and normal ripening would proceed after removal from cold storage, but observations have shown that even fruit that have not been stored show asynchronous ripening. There may be inadequate amounts of the ripening enzymes such as cellulase, polygalacturonase and pectin methyl esterase. A deficiency in one of these enzymes would greatly reduce softening because these enzymes are inter-dependent. Heat shock may synchronize ripening by causing an increase in abscisic acid (ABA) synthesis. Abscisic acid synthesis is increased in response to environmental stress and there is a link between ABA and ethylene (Lafuente *et al.*, 1997) but further work in this regard will be needed. Current opinion on the efficacy of HWT is divided. Woolf *et al.* (1996), Woolf (1997) and Hofman *et al.* (2002a) maintain that HWTs confer protection to avocados stored at ultra-low temperatures. Woolf (1997) claimed that HWTs reduced chilling injury and reduced electrolyte leakage of fruit, which is indicative of cell damage, and suggested a treatment of 38˚C for 60 min as being the treatment that induced the most tolerance to chilling. Hofman *et al.* (2002a) claimed that the effects of HWTs were: reduced external chilling injury and mesocarp fungal infection, and an increased percentage of externally and internally acceptable fruit while Kritzinger *et al*. (1998) concluded that South African 'Hass' proved unresponsive to hot water treatment. Perhaps the benefit of a HWT lies somewhere between these two opinions: while there does seem to be confirmation of the results found by Woolf and Hofman, a question mark still remains over the reliability and repeatability of the treatment. All the benefits reported by these researchers were exhibited in this trial, but there is still some uncertainty as to the most effective treatment. Woolf (1997) recommended that a HWT of 38˚C for 60 min was the best, but in this trial it was observed that fruit that had treatments beyond 38˚C for 15 min exhibited greater external damage and internal disorders. A temperature of 38˚C seems the optimal temperature, thus the optimal duration of the HWT for South African fruit now needs to be ascertained.

Hot water treatment can be revived as a possible solution to reduce chilling injury in avocados as well as contracting the ripening period and improving colour development, but much more work is needed to ensure that consistent results are obtained.

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